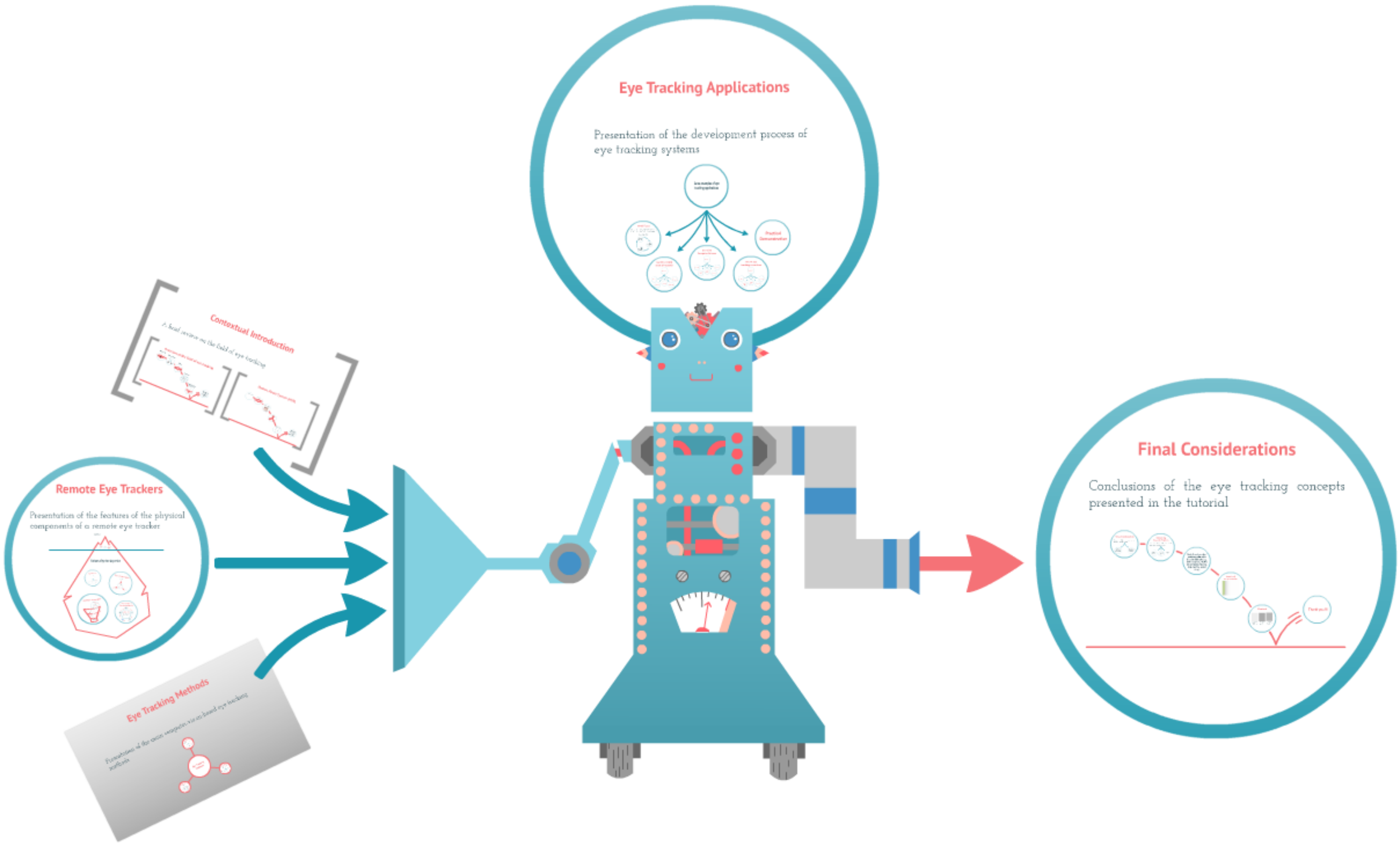


Remote Eye Tracking Systems: Technologies and Applications

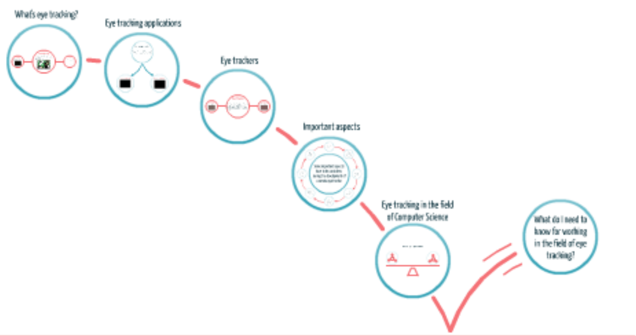
XXVI SIBGRAPI – CONFERENCE ON GRAPHICS, PATTERNS AND IMAGES – AREQUIPA/PERU

Tutorial 03 – Advanced

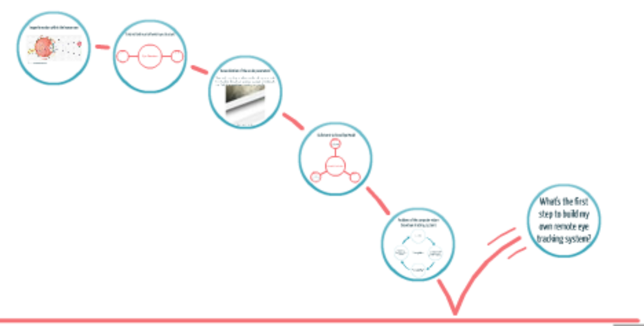
Contextual Introduction

A brief review on the field of eye tracking

Overview of the field of eye tracking



Human Visual System (HVS)



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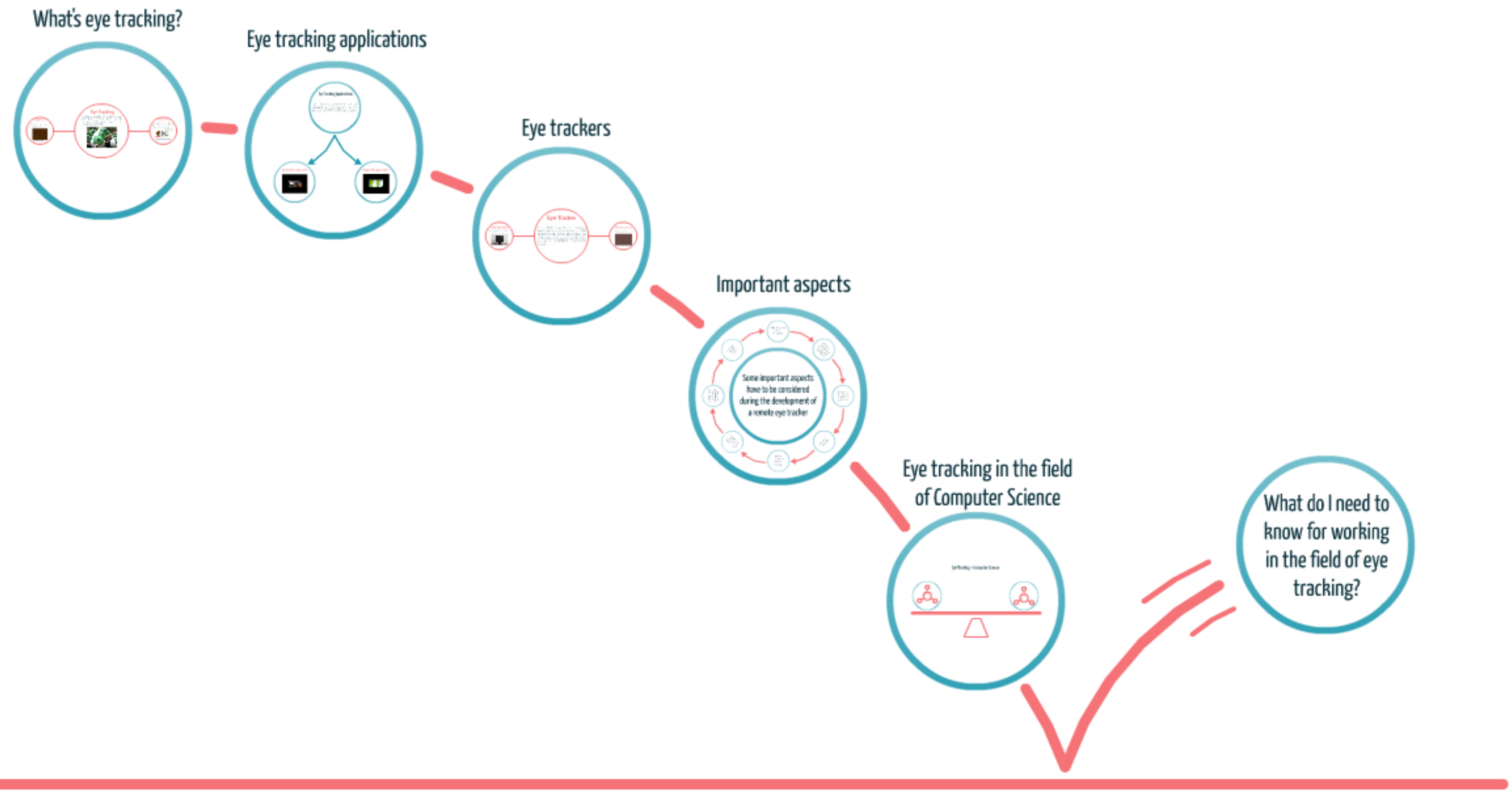

Attention Focus

The focus of attention is the point of highest interest in the user's visual field, also known as "Point of Regard" (PoR) in the literature (GUESTRIN; EIZENMAN, 2008).

Eye Tracking

To aims to estimate the "attention focus" and "gaze direction" based on the monitoring of the user's ocular activities (DUCHOWSKI, 2007).

Gaze Direction

Can be estimated from the identification of the "Line of Sight" (LoS), i.e., the line that represents the visual axis of the eye structure (VILLANUEAVA; CABEZA, 2008).

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Source: Greenpeace

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Source: http://ilab.usc.edu/itrack/doc/114-1496_IMG.JPG

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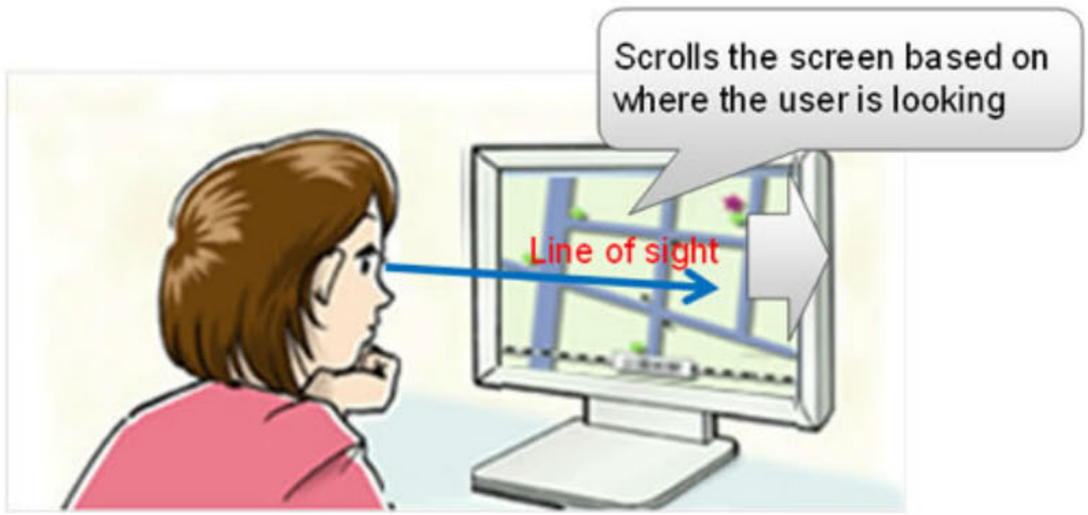
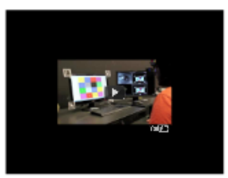


Source: http://cdn.physorg.com/newman/gfx/news/hires/2012/28-fujitsudevel.jpg

Eye Tracking Applications

Eye tracking applications can be classified as: (i) interactive or (ii) diagnostic (CERROLAZA et al., 2012).

Interactive Application



Diagnostic Application

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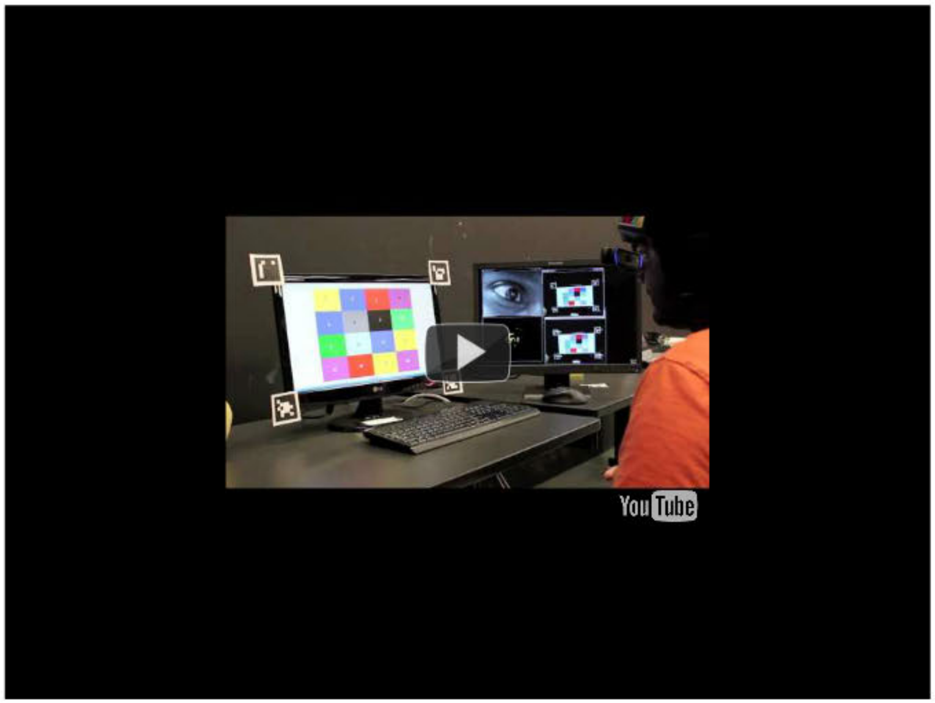
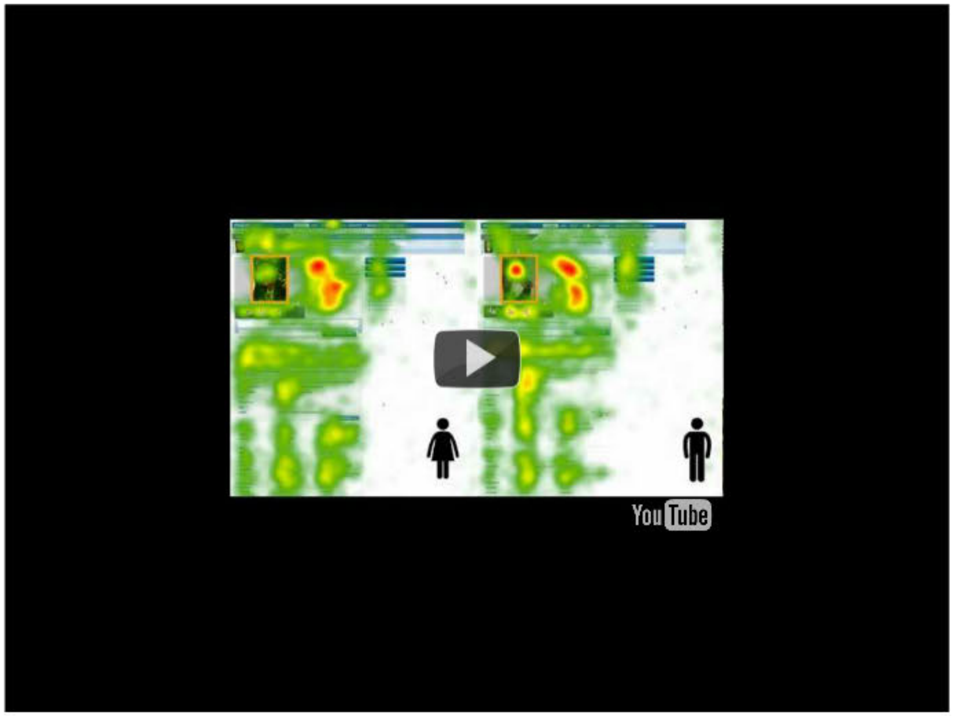


Diagnostic Application



Eye Tracker

It is a device responsible for measuring ocular activities and estimating the PoR (DUCHOWSKI, 2007). Eye trackers can be classified as: (i) remote; and (ii) head-mounted (HENNESSEY; LAWRENCE, 2009).

Remote Eye Tracker

Their components do not require any attachments to the user's body.

Head-Mounted Eye Tracker

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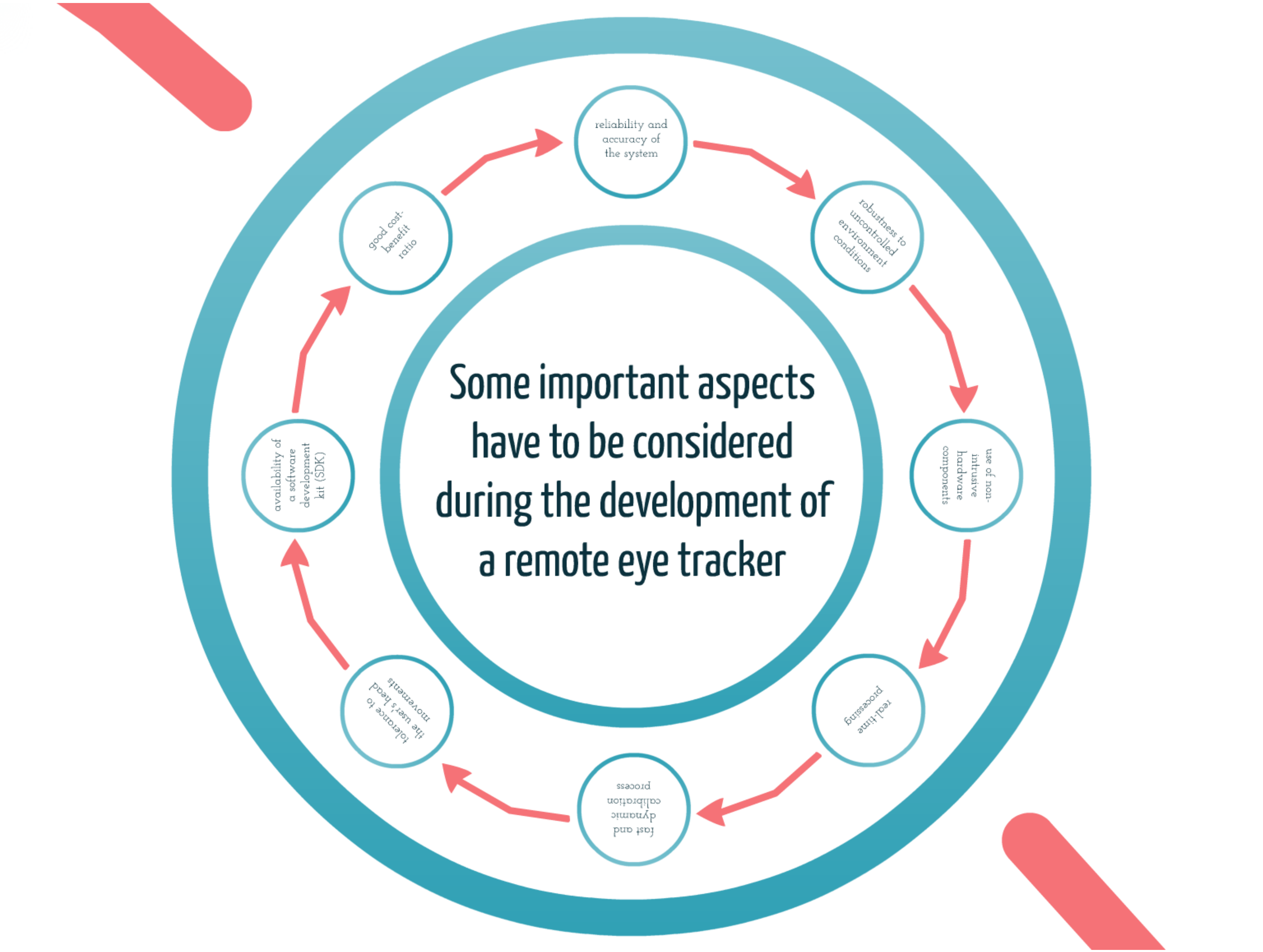
Some important aspects have to be considered during the development of a remote eye tracker
reliability and accuracy of the system
robustness to uncontrolled environment conditions
use of non-intrusive hardware components
real-time processing
fast and dynamic calibration process
tolerance to the user's head movements
availability of a software development kit (SDK)
good cost-benefit ratio

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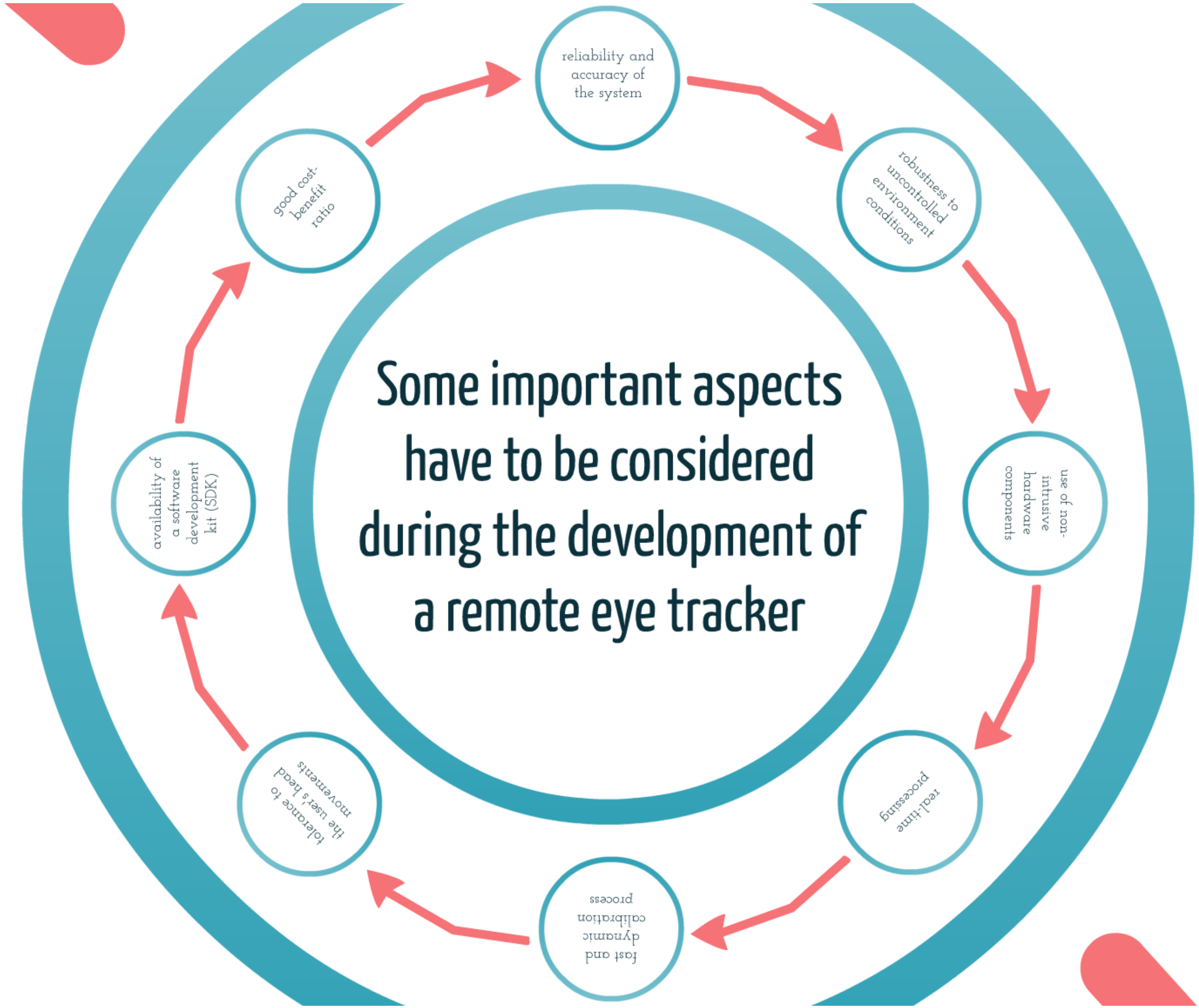

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Eye Tracking + Computer Science


Feature 01
The existence of low-cost of video capture devices (cameras);
Eye tracking in the field of Computer Science
In the field of Computer Science, the video-based eye tracking methods are of particular interest mainly due to the following features (DUCHOWSKI, 2007):
Feature 03
The non-intrusive nature of the capture device
Feature 02
The existence of real-time digital image processing algorithms

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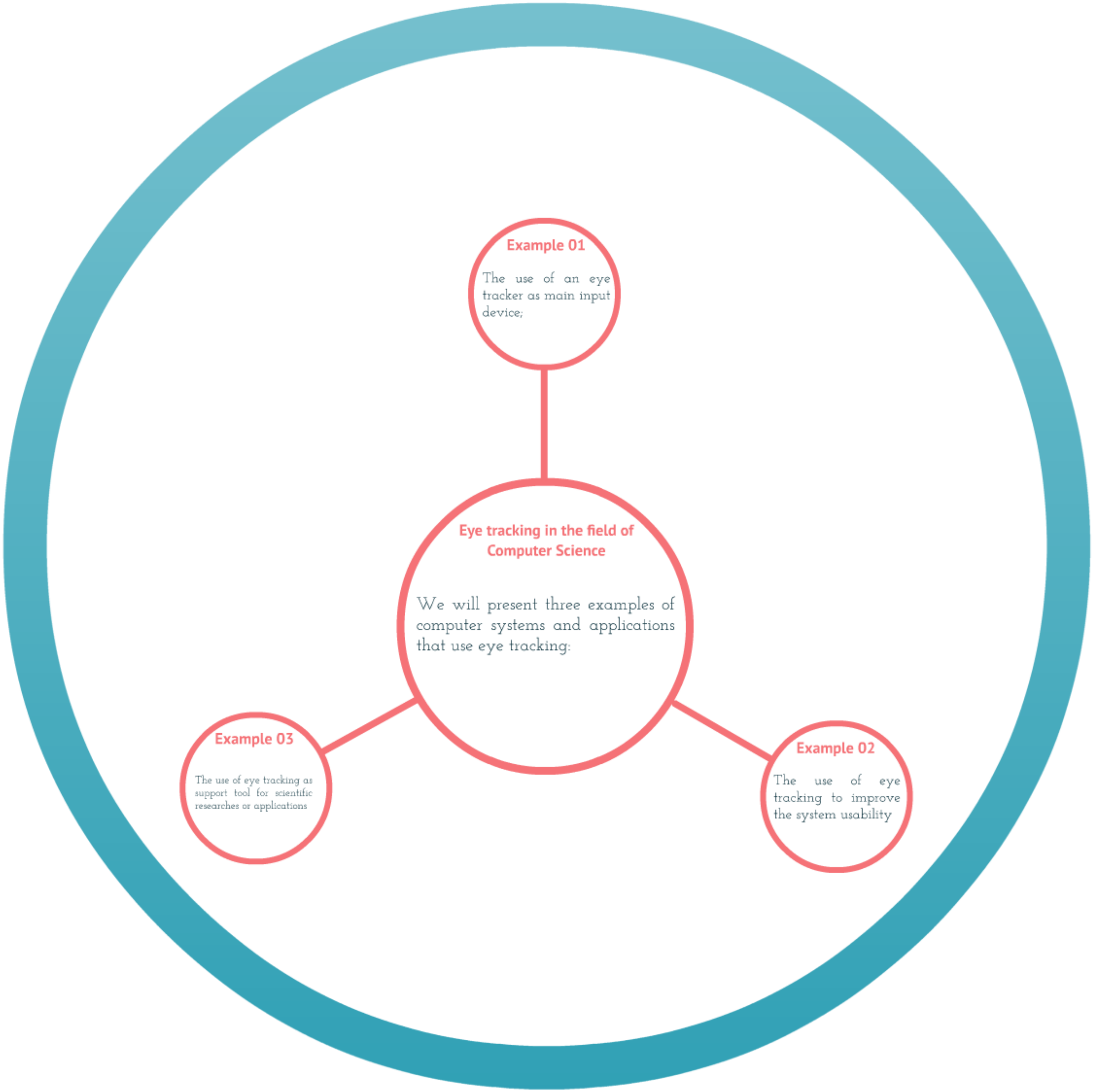

Example 01
The use of an eye tracker as main input device;
Eye tracking in the field of Computer Science
We will present three examples of computer systems and applications that use eye tracking:
Example 03
The use of eye tracking as support tool for scientific researches or applications
Example 02
The use of eye tracking to improve the system usability

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What do I need to know for working in the field of eye tracking?

Human Visual System (HVS)

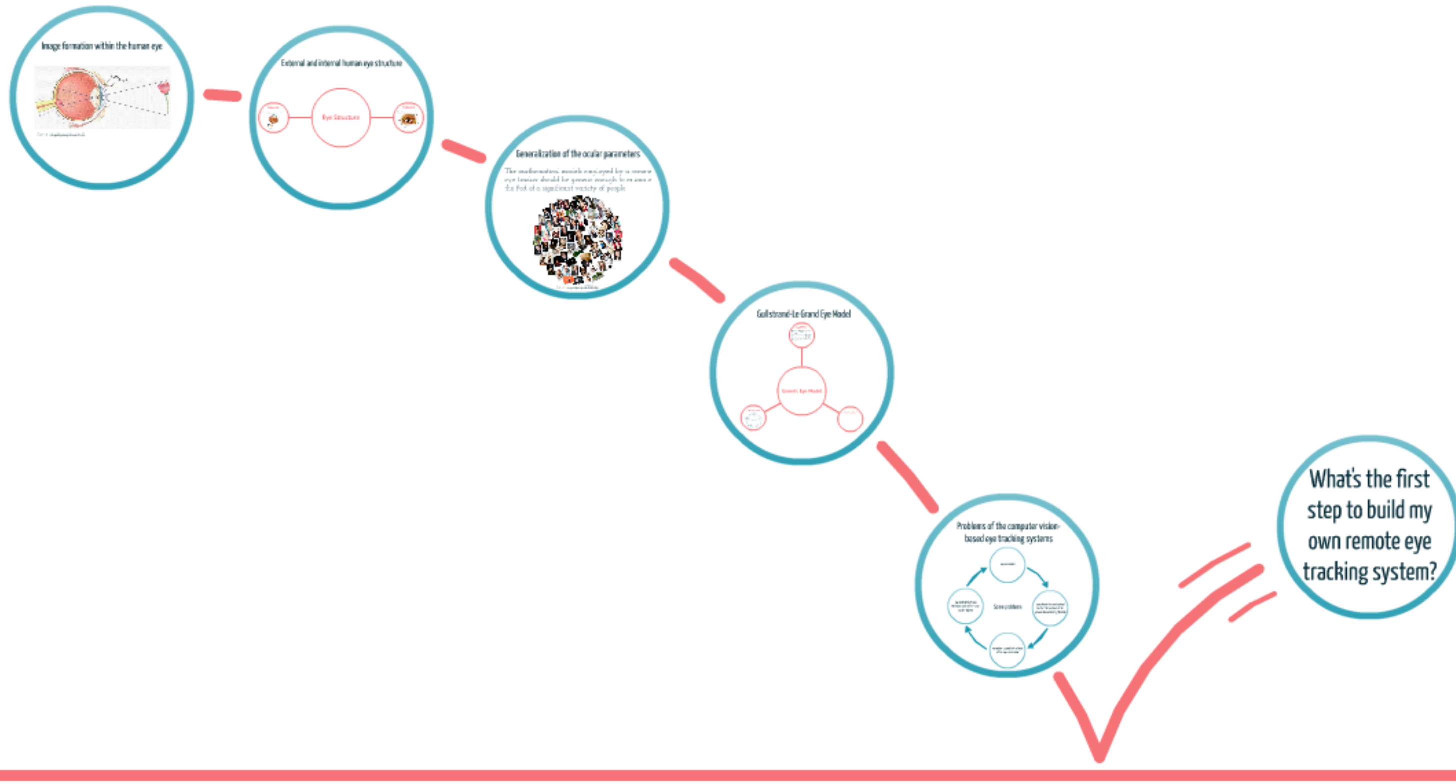
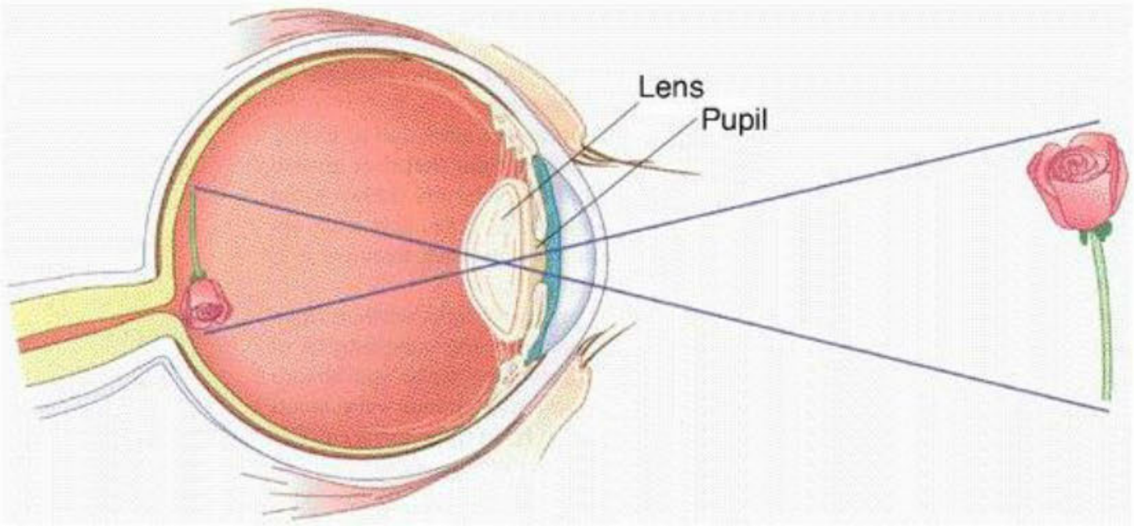


Image formation within the human eye



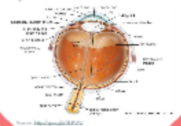
Source: http://goo.gl/vwMBR

External and internal human eye structure

Eye Structure

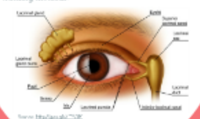
Internal

Which are eye features used by 3D model-based eye tracking methods?



External

Which are eye features used by 2D model-based eye tracking methods?



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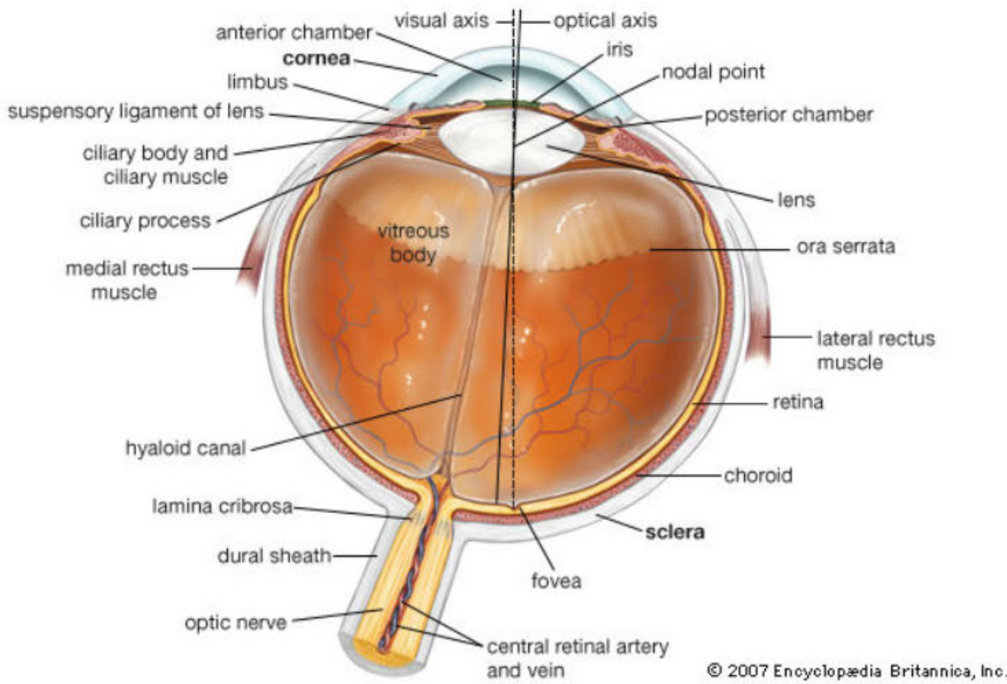
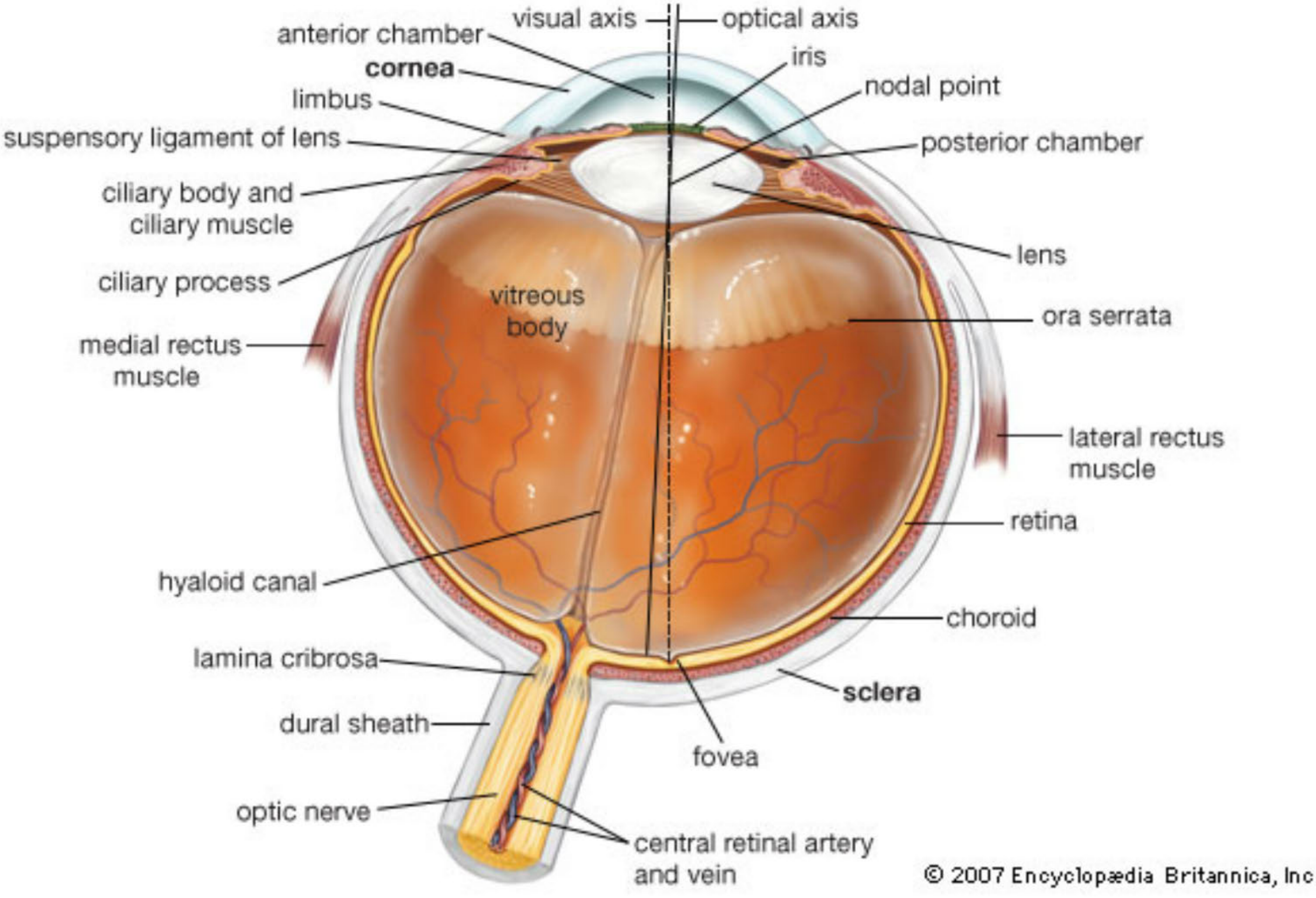


Source: http://goo.gl/OlLPVV

ing methods:



visual axis
optical axis
anterior chamber
cornea
iris
limbus
nodal point
suspensory ligament of lens
posterior chamber
ciliary body and ciliary muscle
lens
ciliary process
vitreous body
ora serrata
medial rectus muscle
lateral rectus muscle
retina
hyaloid canal
choroid
lamina cribrosa
sclera
dural sheath
fovea
optic nerve
central retinal artery and vein
© 2007 Encyclopædia Britannica, Inc.

External

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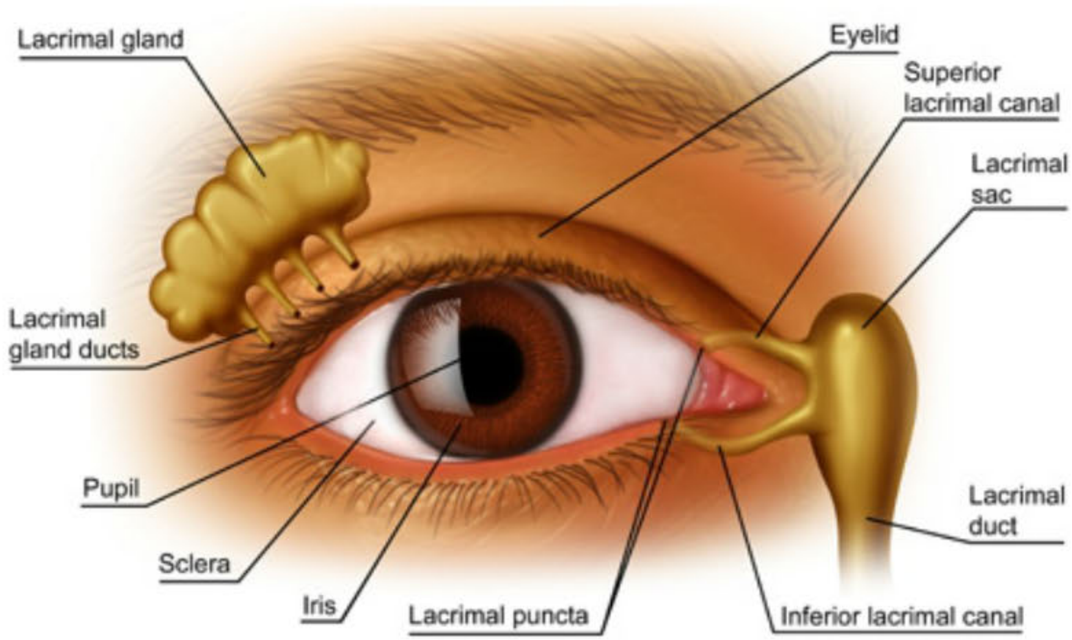
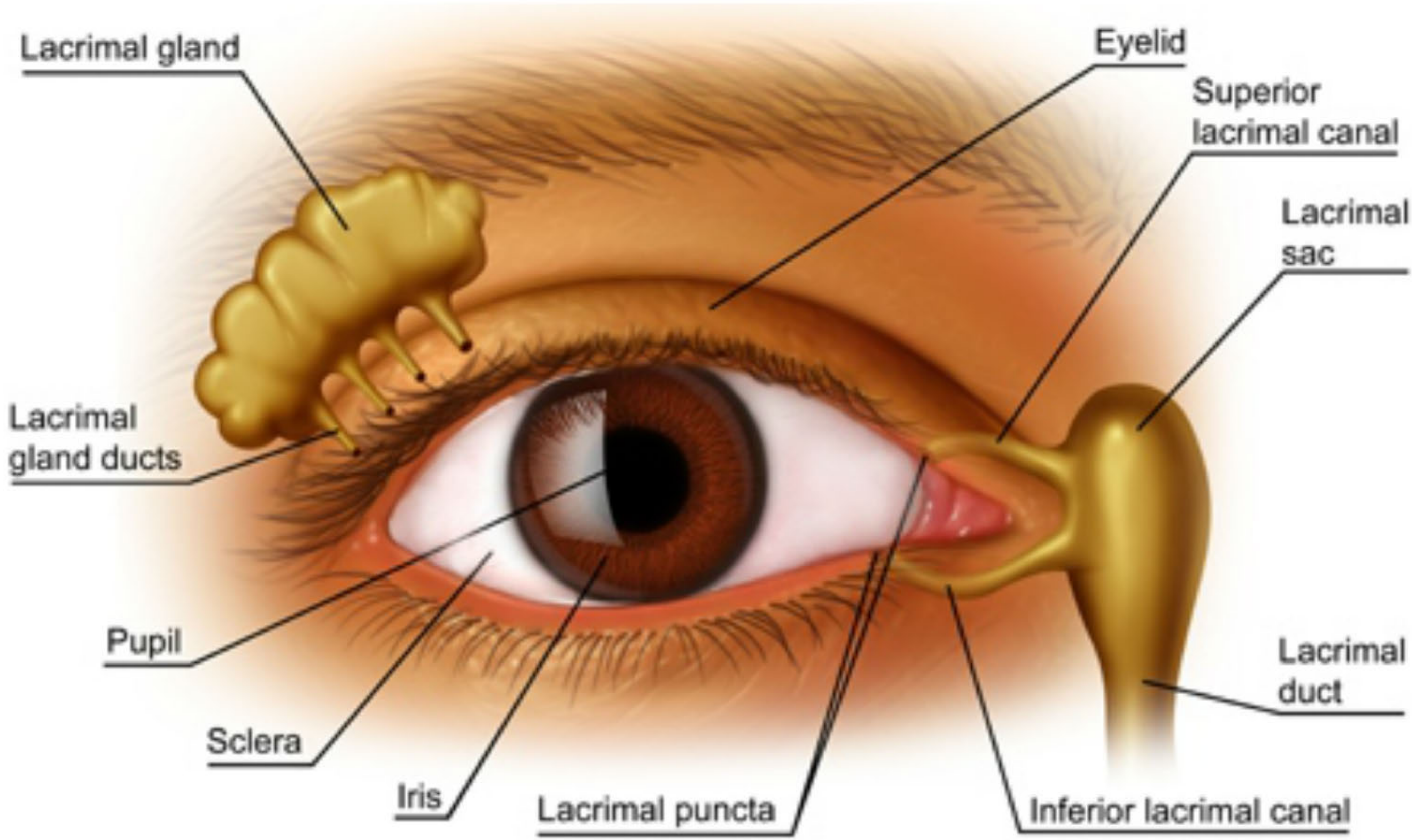


Source: http://goo.gl/dTPOK

cking methods?



Source: http://goo.gl/dTPOK

Generalization of the ocular parameters

The mathematical models employed by a remote eye tracker should be generic enough to estimate the PoR of a significant variety of people

Source: http://goo.gl/XTWe7y

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Gullstrand-Le Grand Eye Model

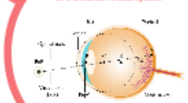
What's Gullstrand-Le Grand Eye Model?

It's a model that can be used directly for estimating the PoR as well as for performing simulations of the eye tracking methods (HENNESSEY, LAWRENCE, 2009; COUTINHO, MORIMOTO, 2012; MORIMOTO et al., 2002)

Generic Eye Model

Main Eye Features

Simplified mathematical model of the human visual system



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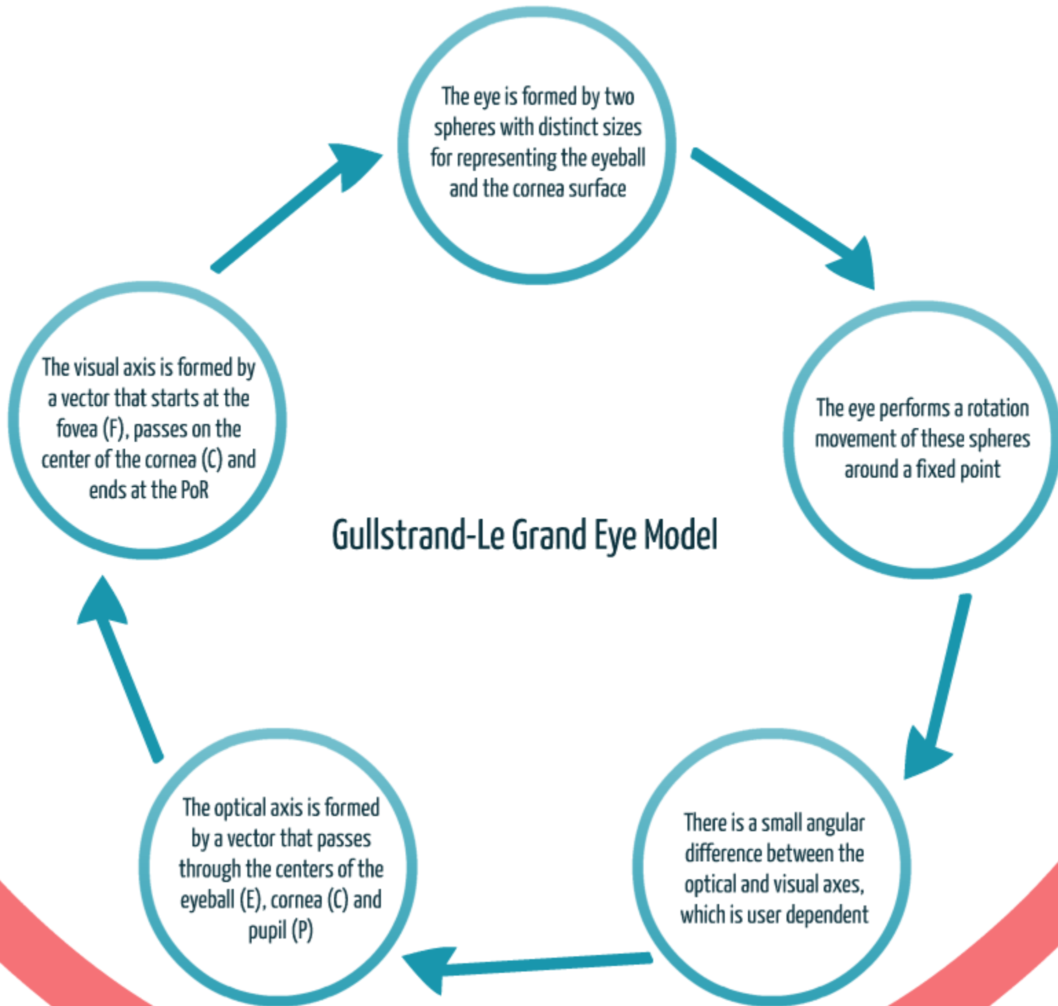


The eye is formed by two spheres with distinct sizes for representing the eyeball and the cornea surface

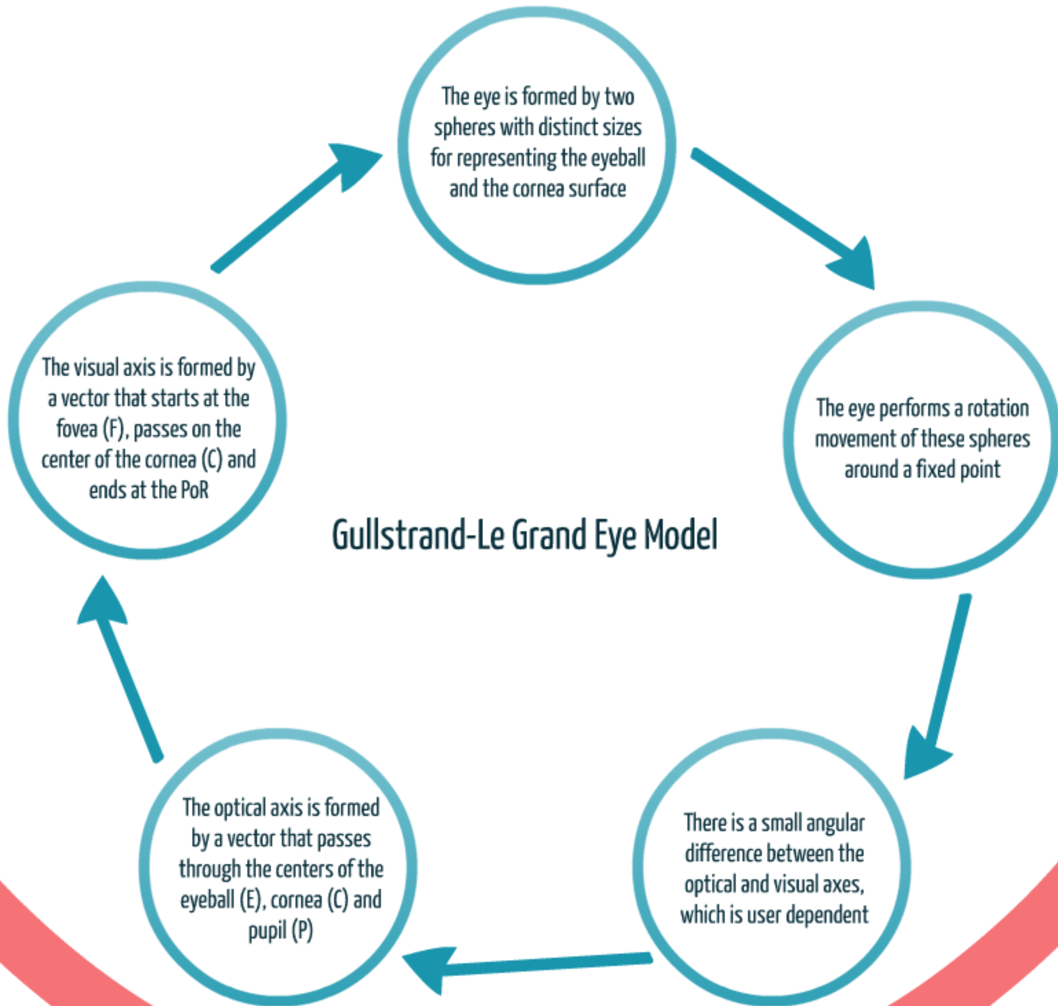
The eye performs a rotation movement of these spheres around a fixed point

There is a small angular difference between the optical and visual axes, which is user dependent

The optical axis is formed by a vector that passes through the centers of the eyeball (E), cornea (C) and pupil (P)

The visual axis is formed by a vector that starts at the fovea (F), passes on the center of the cornea (C) and ends at the PoR

Main Eye Features



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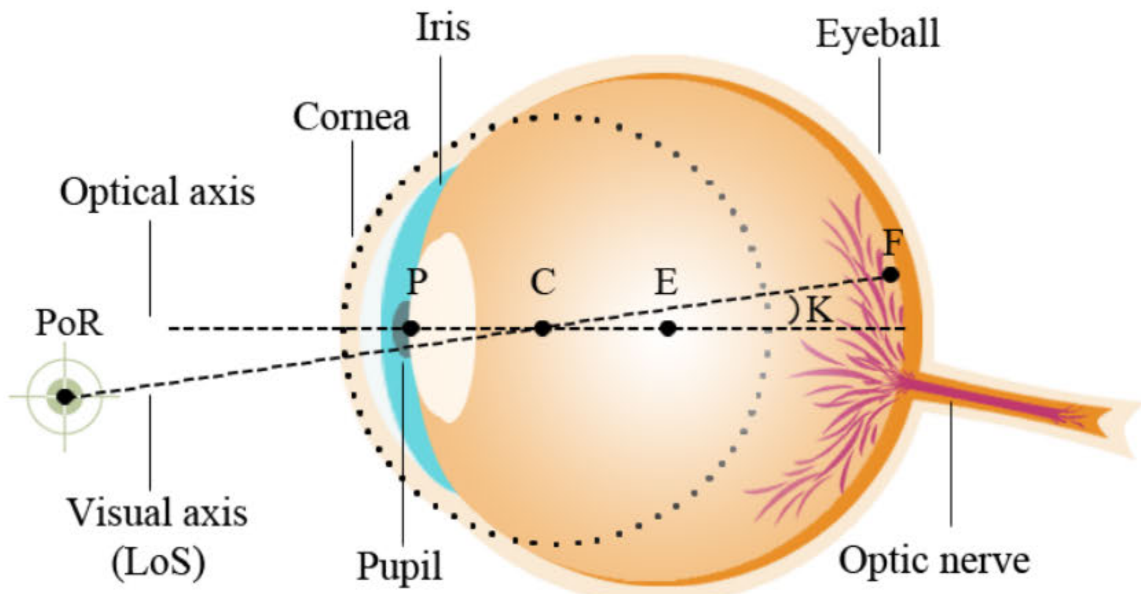
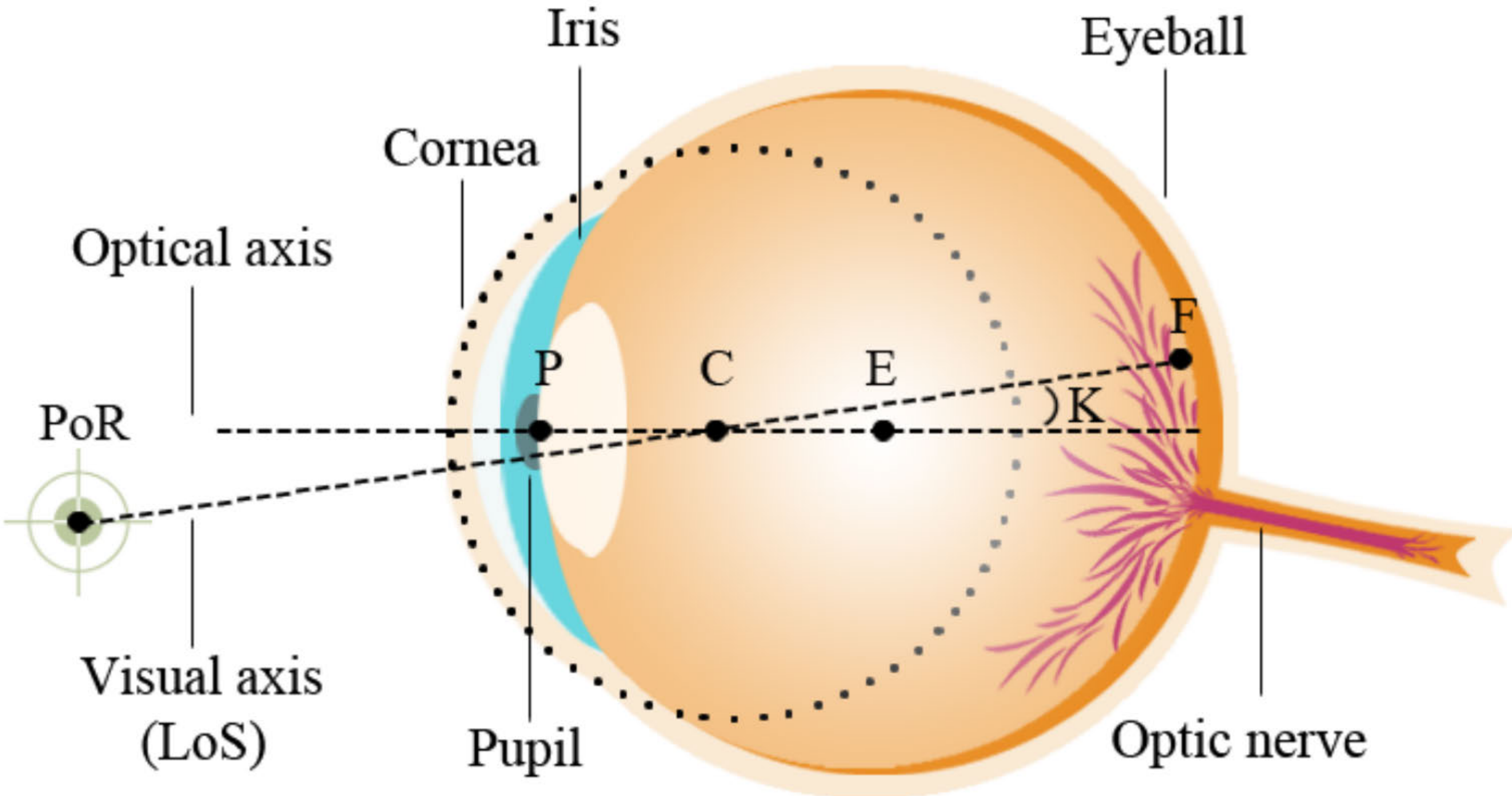
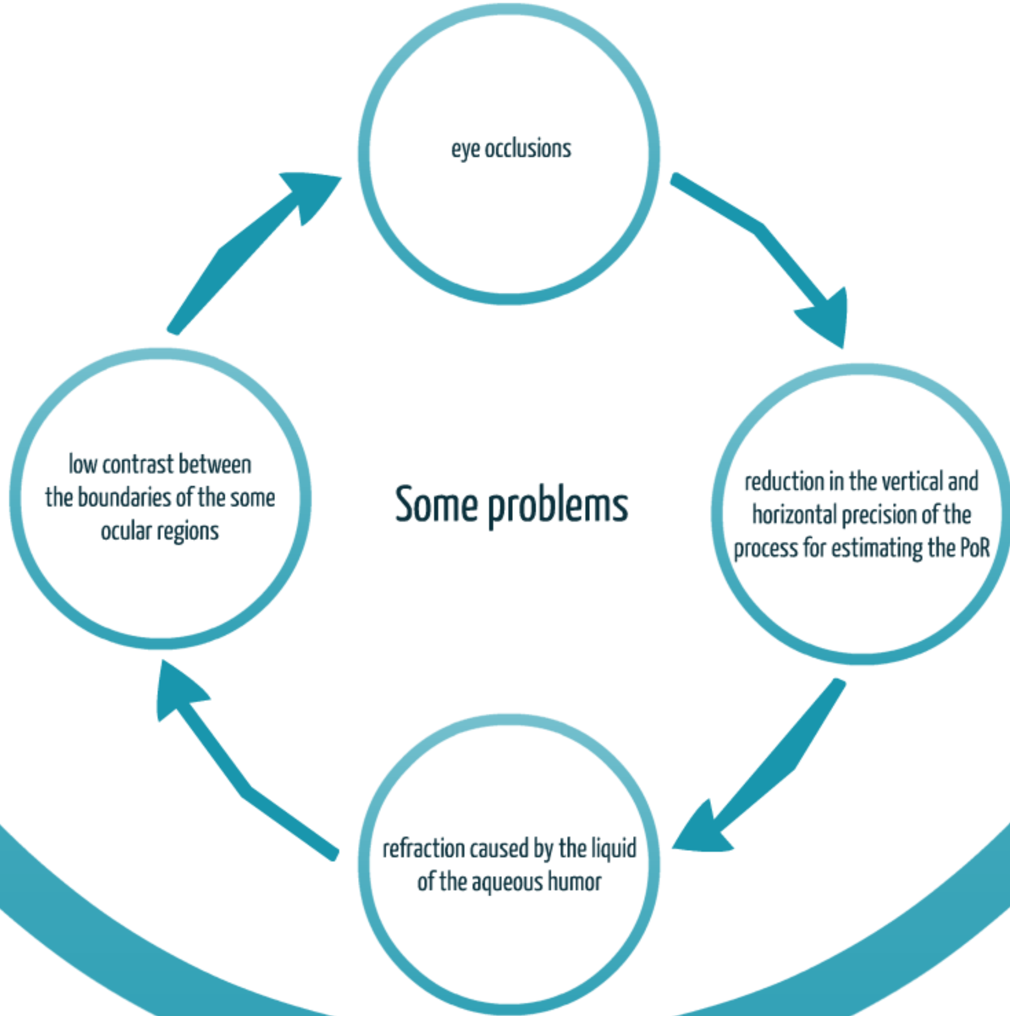



Iris
Eyeball
Cornea
Optical axis
F
P
C
E
K
PoR
Visual axis
(LoS)
Pupil
Optic nerve

Problems of the computer vision-based eye tracking systems



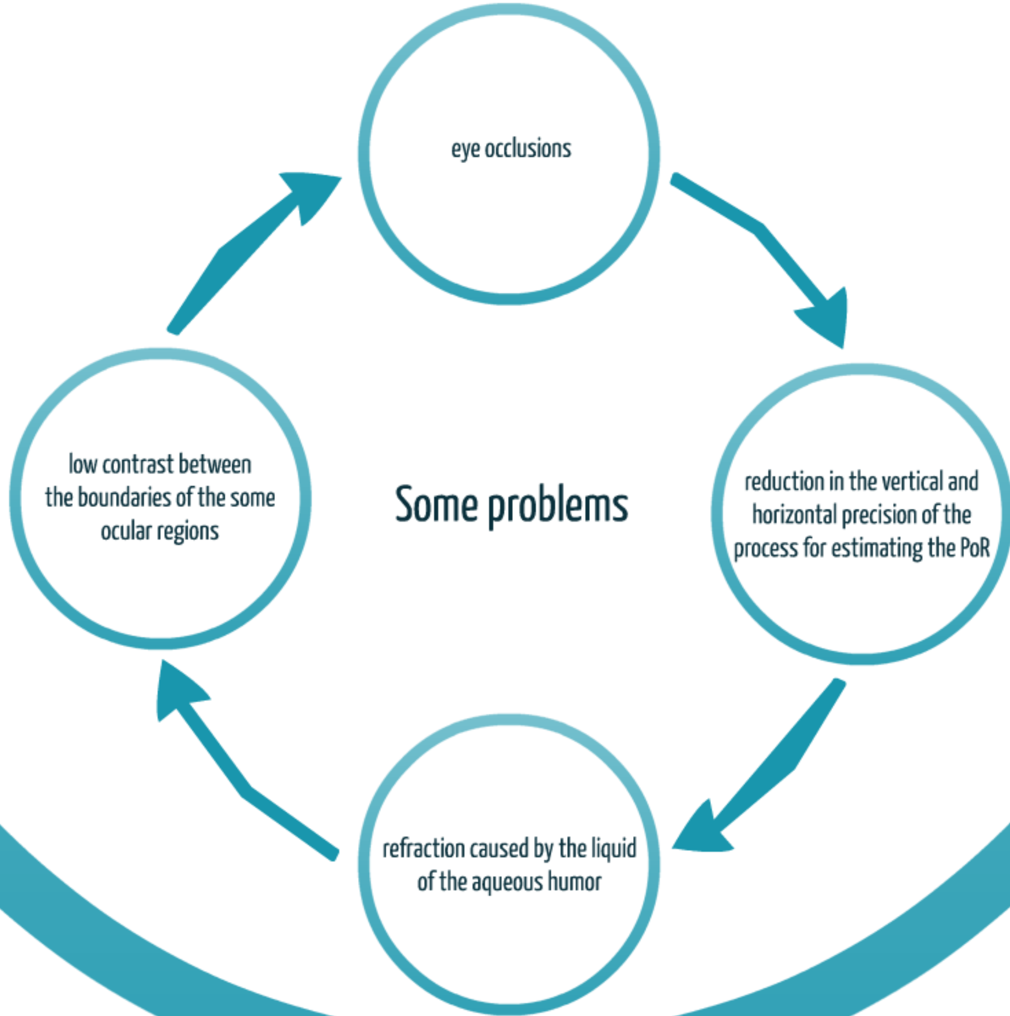
eye occlusions

reduction in the vertical and horizontal precision of the process for estimating the PoR

refraction caused by the liquid
of the aqueous humor

low contrast between
the boundaries of the some
ocular regions

Problems of the computer vision-based eye tracking systems

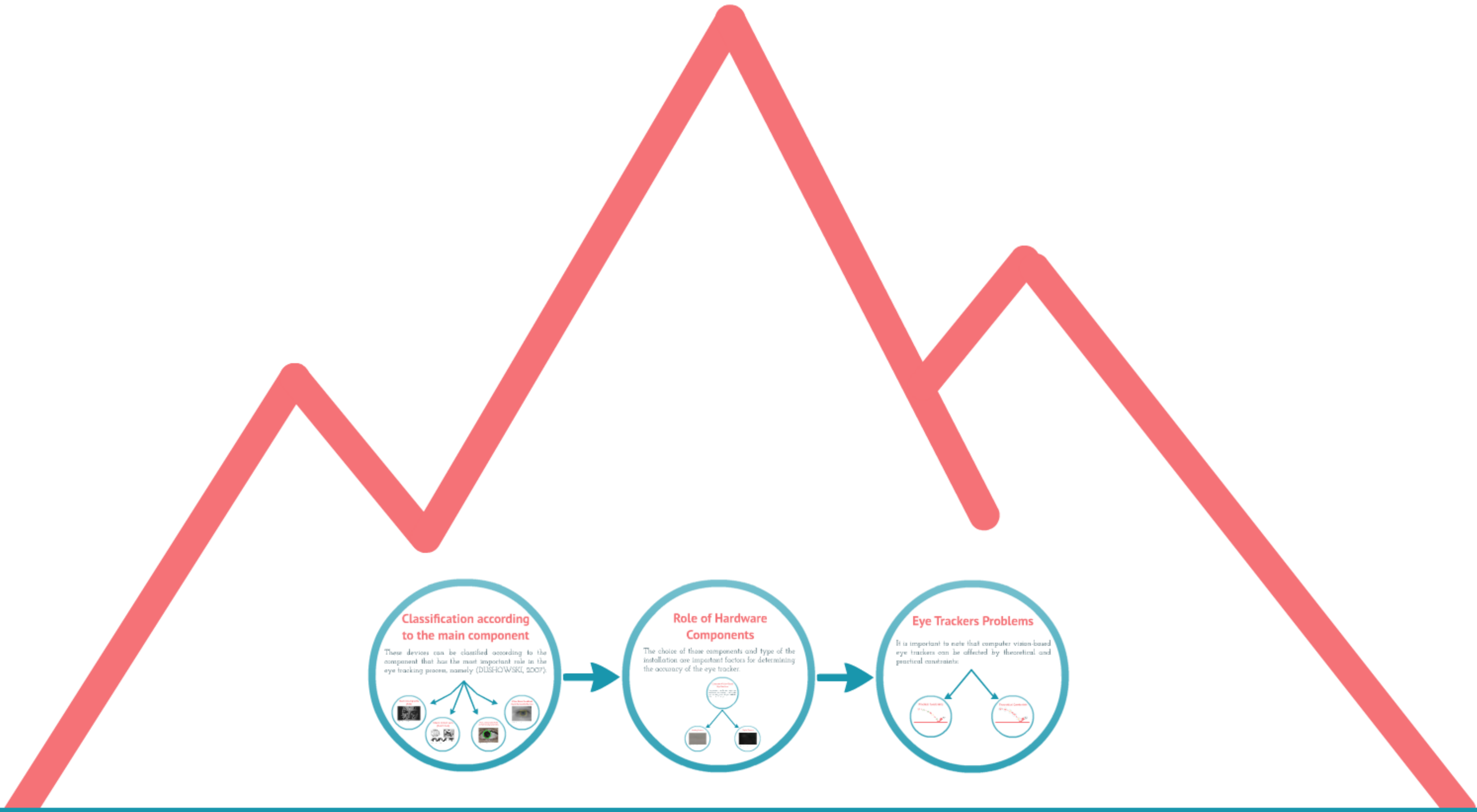


What's the first step to build my own remote eye tracking system?

Remote Eye Trackers

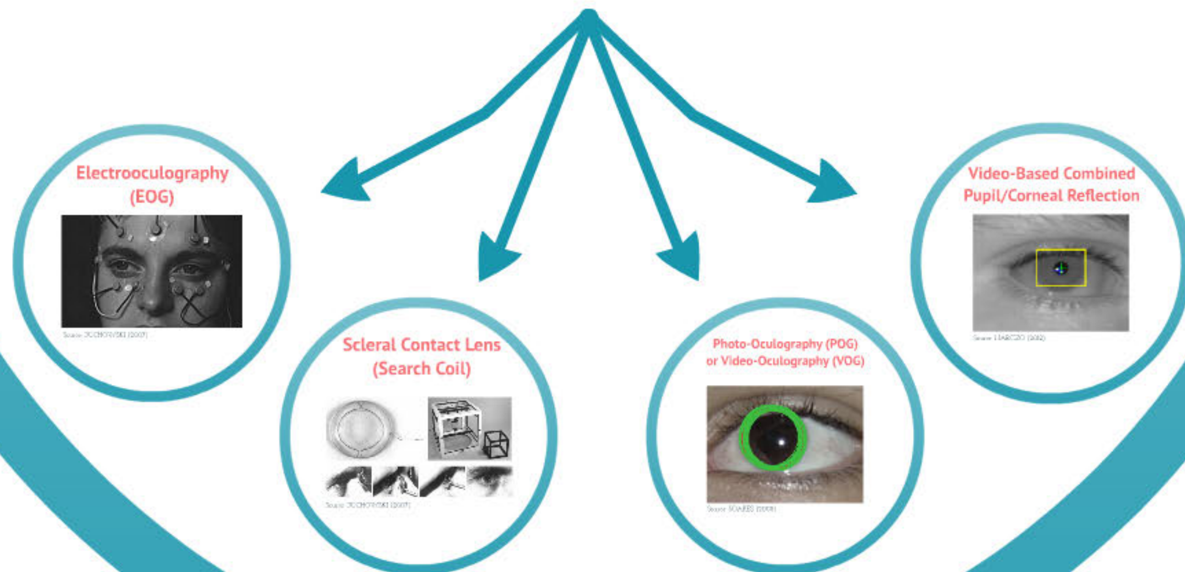
Presentation of the features of the physical components of a remote eye tracker

A Remote Eye Tracker



Classification according to the main component

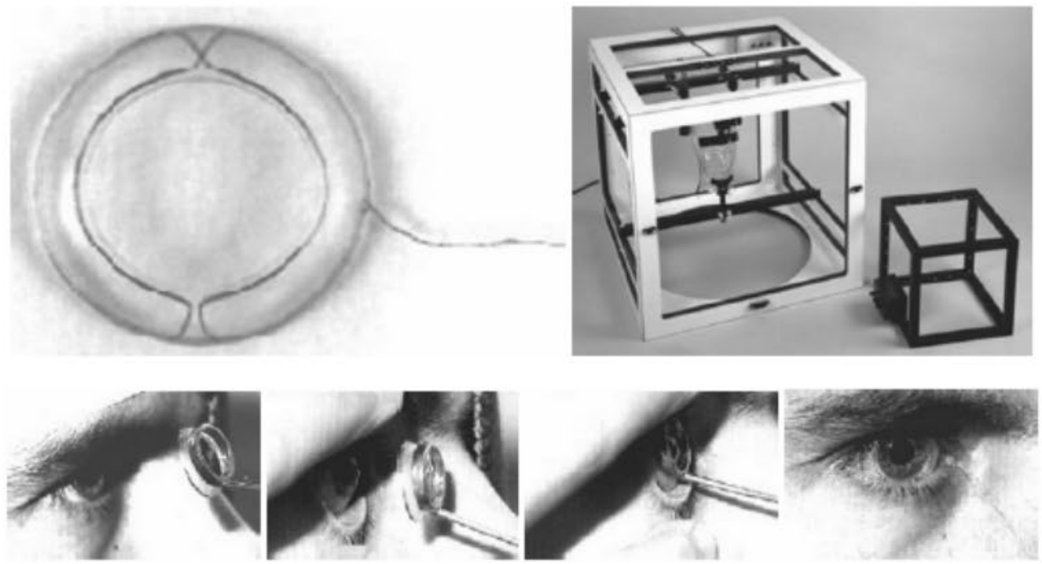
These devices can be classified according to the component that has the most important role in the eye tracking process, namely (DUSHOWSKI, 2007):



Electrooculography (EOG)

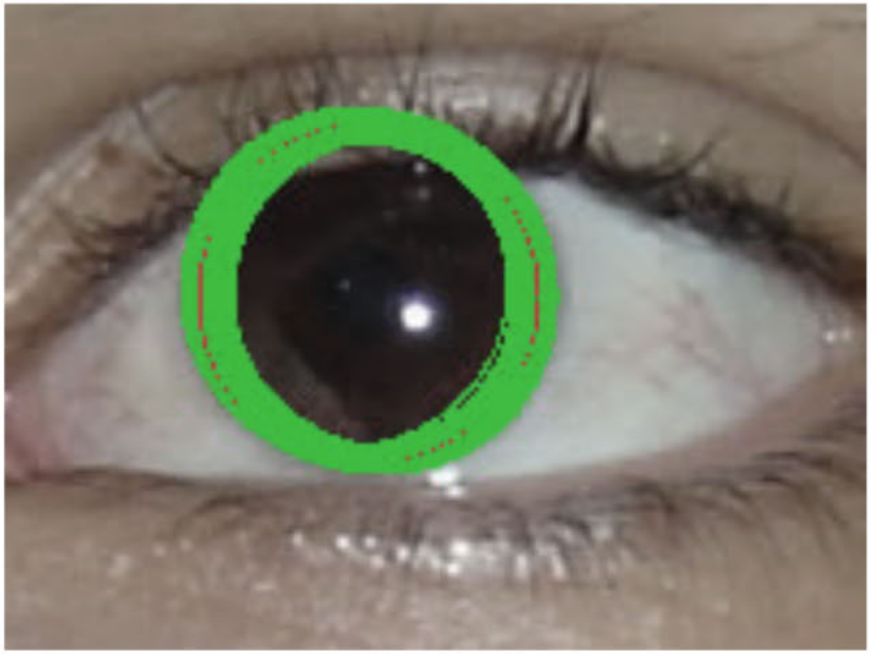
Source: DUCHOWSKI (2007)

Scleral Contact Lens (Search Coil)



Source: DUCHOWSKI (2007)

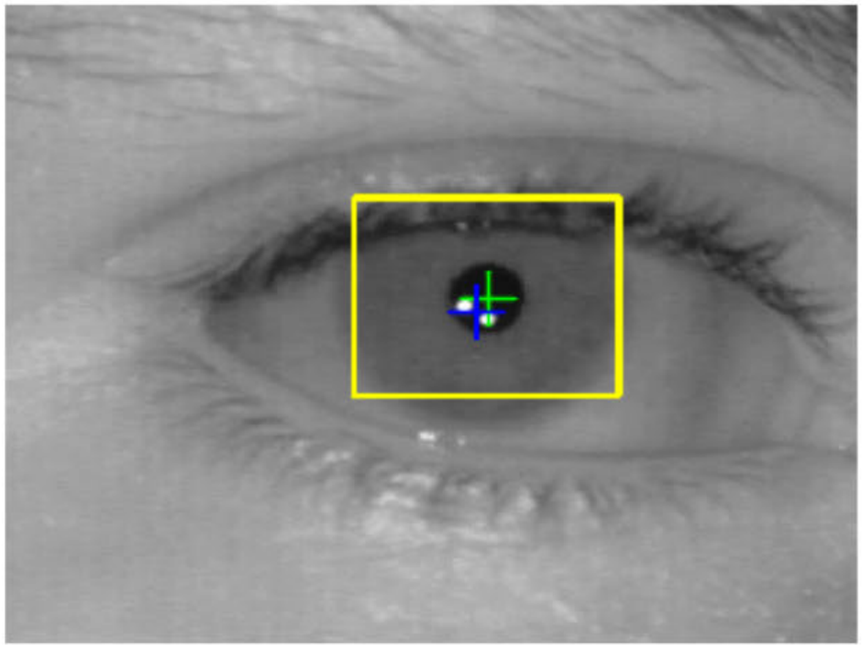
Photo-Oculography (POG) or Video-Oculography (VOG)



Source: SOARES (2008)

S

Video-Based Combined Pupil/Corneal Reflection



Source: NARCIZO (2012)

Role of Hardware Components

The choice of those components and type of the installation are important factors for determining the accuracy of the eye tracker.

Computer Vision-Based Eye Trackers

The camera is one the most important hardware components, because the eye tracking process begins with the capture of eye images

Analog Camera

Digital Camera

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Analog Camera

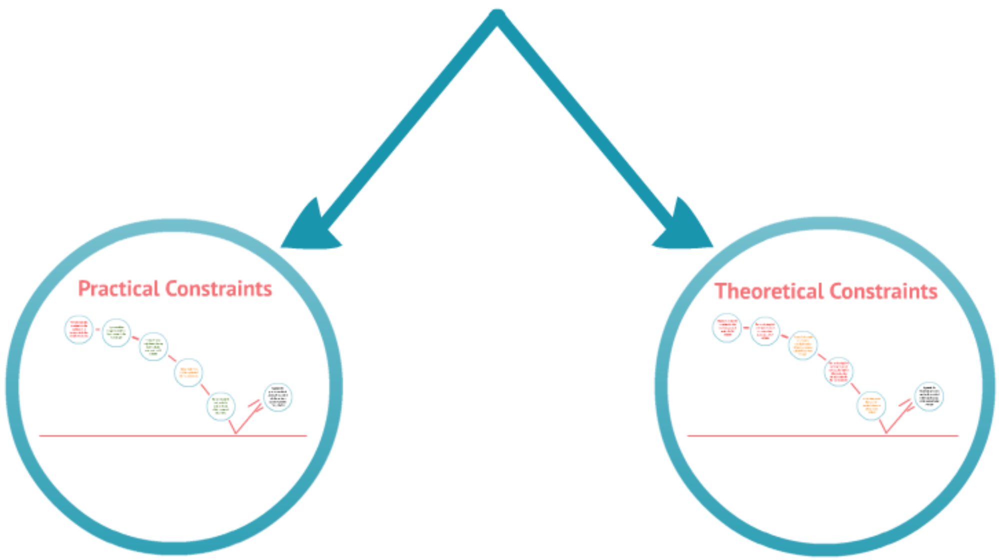
Source: NARCIZO (2012)

Digital Camera

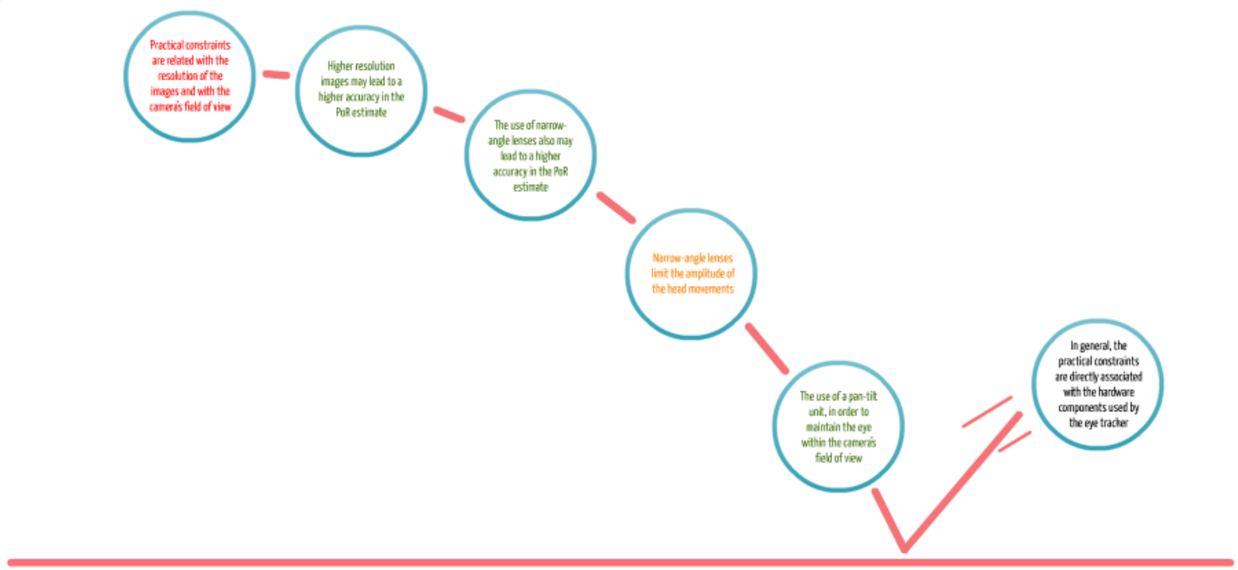
Source: NARCIZO (2012)

Eye Trackers Problems

It is important to note that computer vision-based eye trackers can be affected by theoretical and practical constraints:



Practical Constraints



Practical constraints are related with the resolution of the images and with the camera's field of view

Higher resolution images may lead to a higher accuracy in the PoR estimate

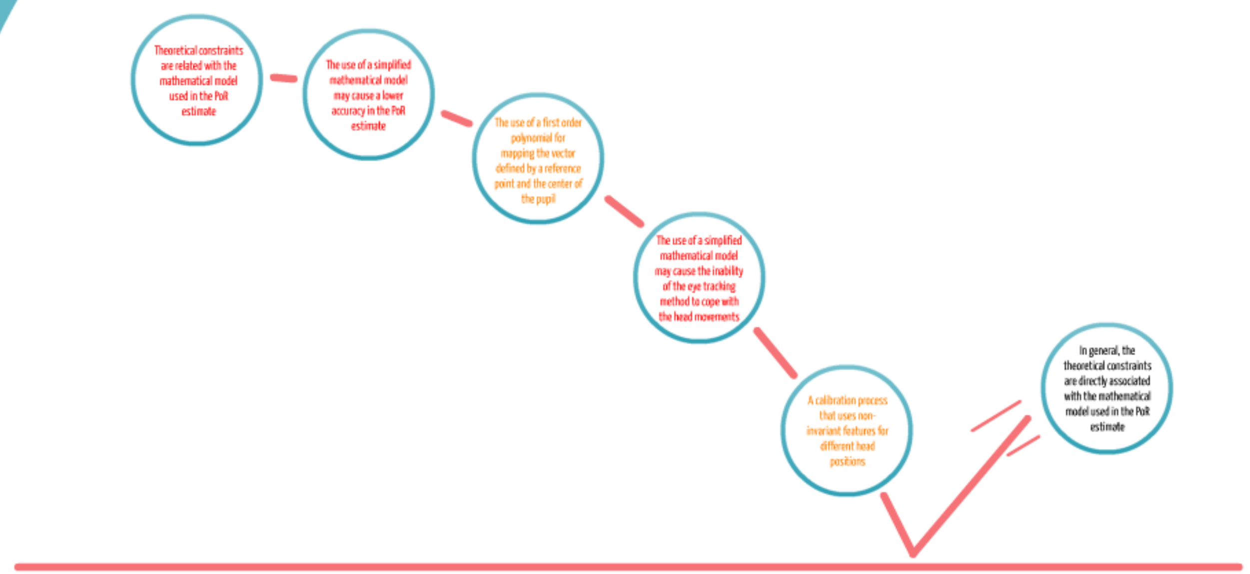
The use of narrow-angle lenses also may lead to a higher accuracy in the PoR estimate

Narrow-angle lenses limit the amplitude of the head movements

The use of a pan-tilt unit, in order to maintain the eye within the camera's field of view

In general, the practical constraints are directly associated with the hardware components used by the eye tracker

Theoretical Constraints



Theoretical constraints are related with the mathematical model used in the PoR estimate

The use of a simplified mathematical model may cause a lower accuracy in the PoR estimate

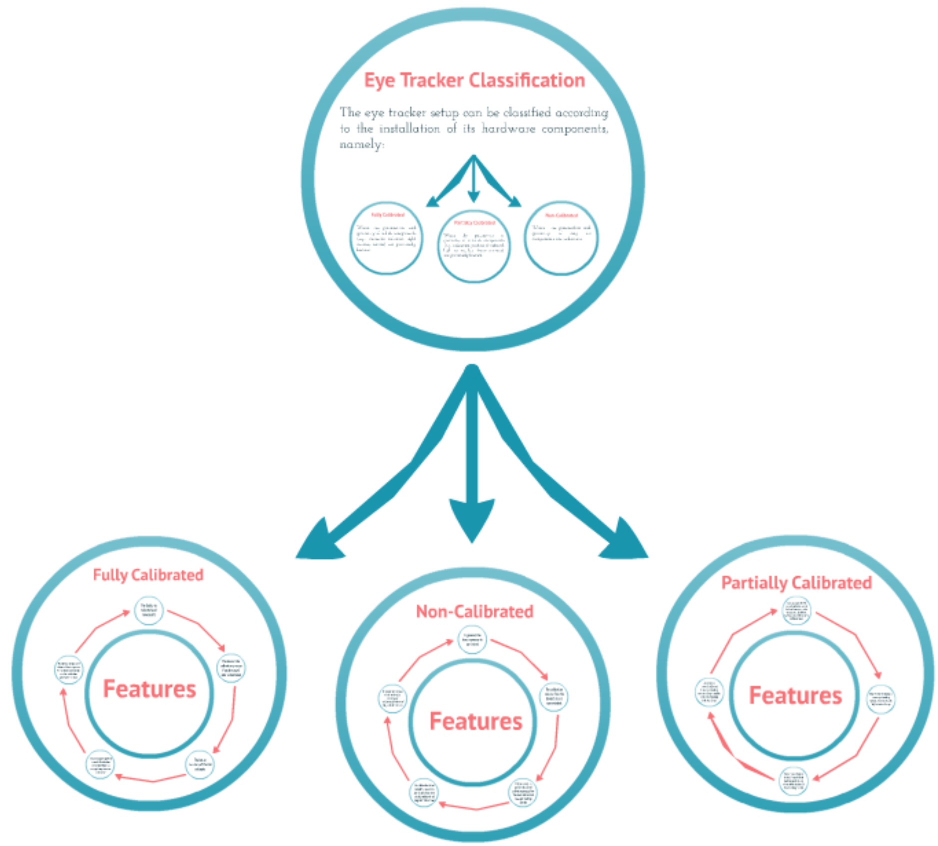
The use of a first order polynomial for mapping the vector defined by a reference point and the center of the pupil

The use of a simplified mathematical model may cause the inability of the eye tracking method to cope with the head movements

A calibration process that uses non-invariant features for different head positions

In general, the theoretical constraints are directly associated with the mathematical model used in the PoR estimate

Types of setup



Eye Tracker Classification

The eye tracker setup can be classified according to the installation of its hardware components, namely:

Fully Calibrated

When the parameters and geometry of all its components (e.g., cameras, infrared light sources, screen) are previously known

Partially Calibrated

When the parameters or geometry of some its components (e.g., unknown position of infrared light sources, but stereo cameras) are previously known

Non-Calibrated

When the parameters and geometry of any its components are unknown

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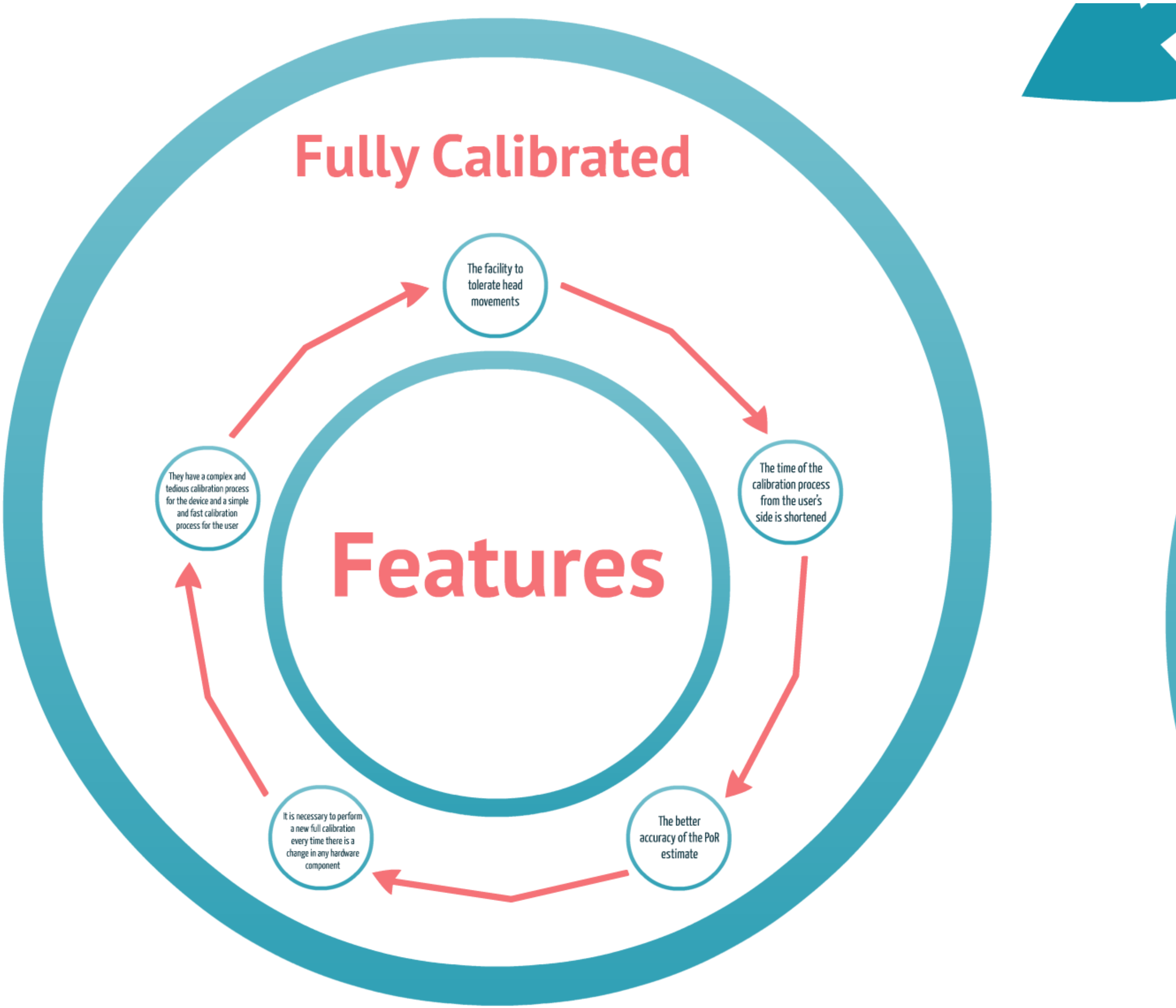
Fully Calibrated
Features
The facility to tolerate head movements
The time of the calibration process from the user's side is shortened
The better accuracy of the PoR estimate
It is necessary to perform a new full calibration every time there is a change in any hardware component
They have a complex and tedious calibration process for the device and a simple and fast calibration process for the user

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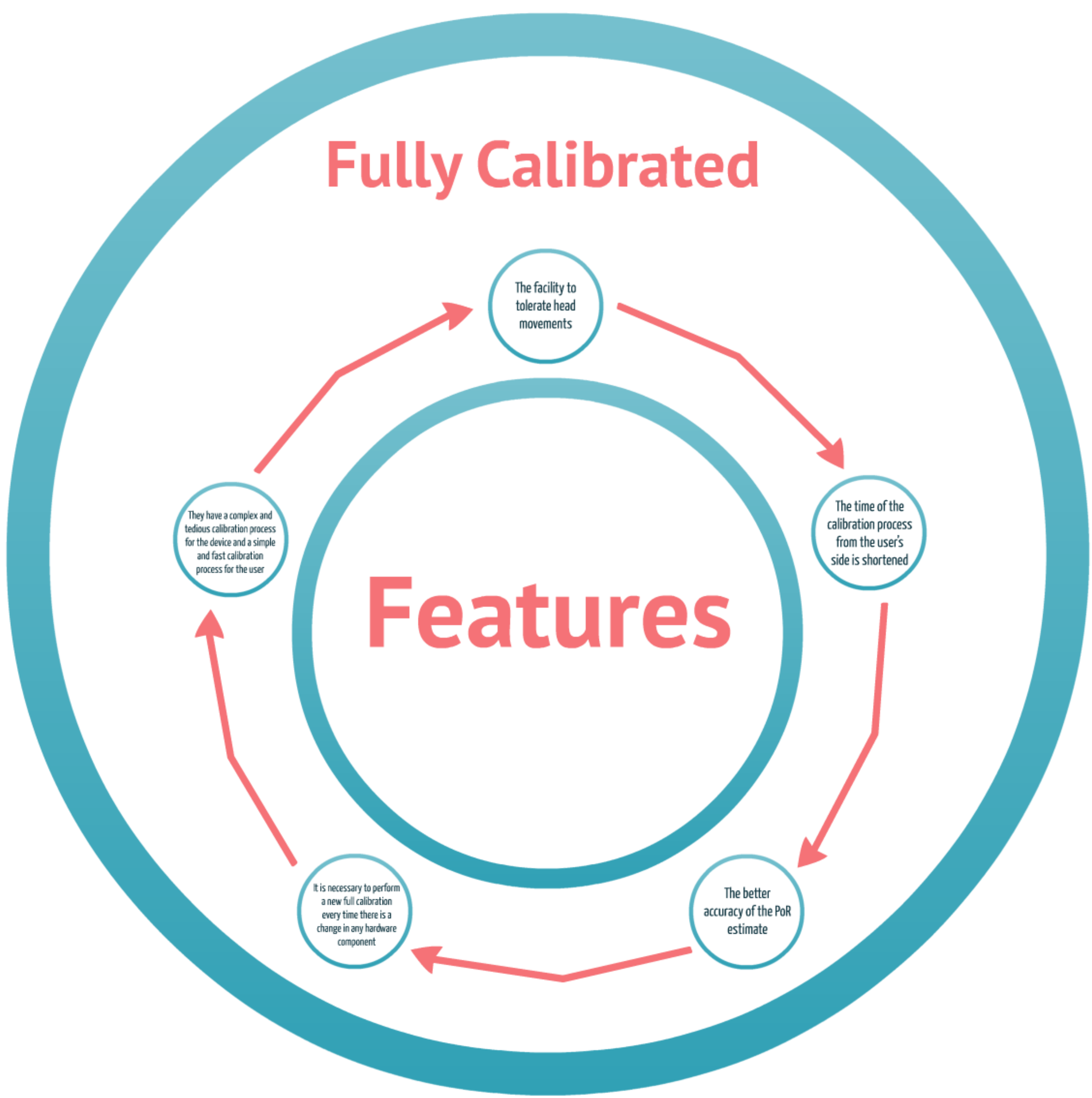
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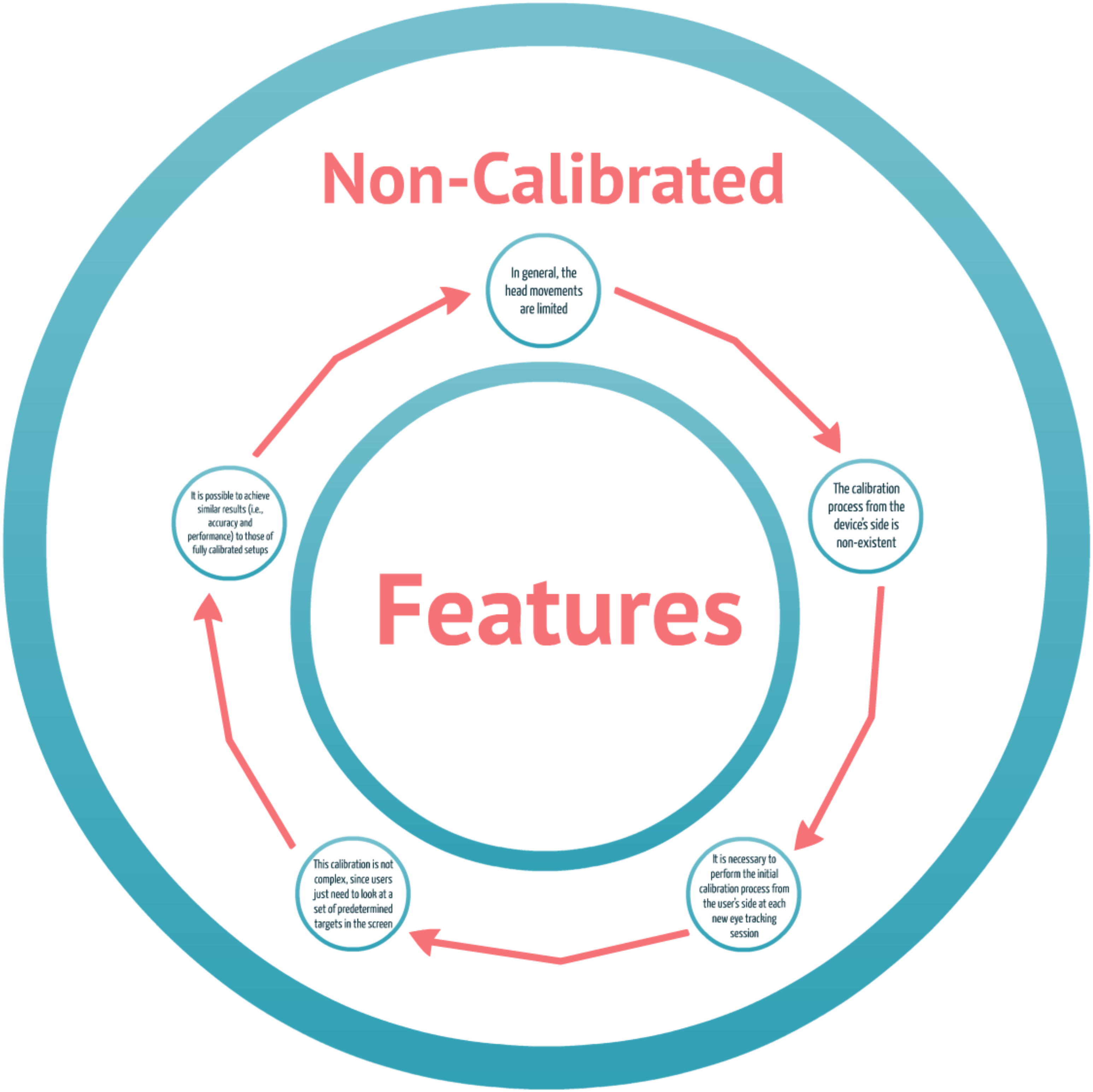
Non-Calibrated
Features
In general, the head movements are limited
The calibration process from the device's side is non-existent
It is necessary to perform the initial calibration process from the user's side at each new eye tracking session
This calibration is not complex, since users just need to look at a set of predetermined targets in the screen
It is possible to achieve similar results (i.e., accuracy and performance) to those of fully calibrated setups

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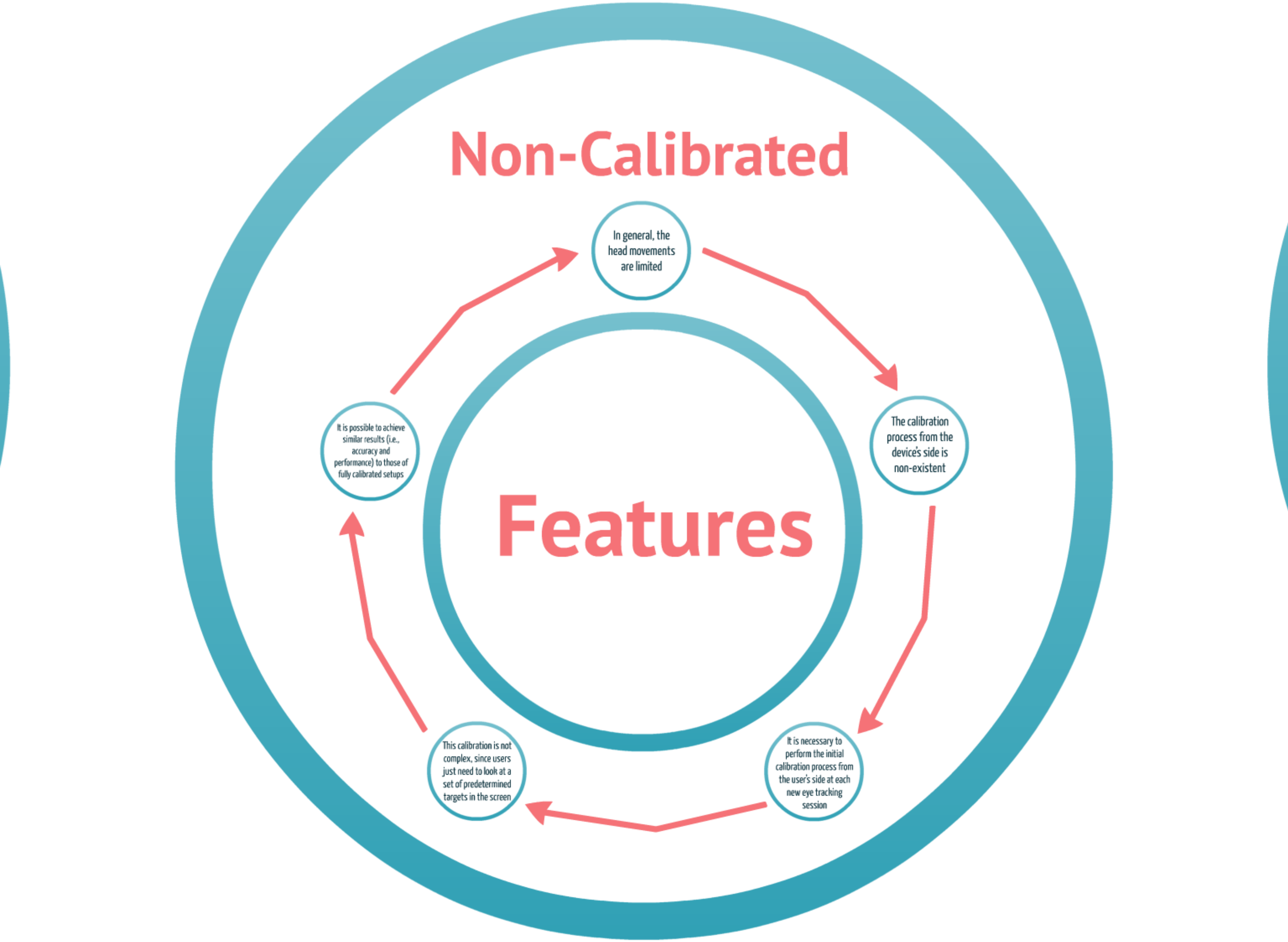

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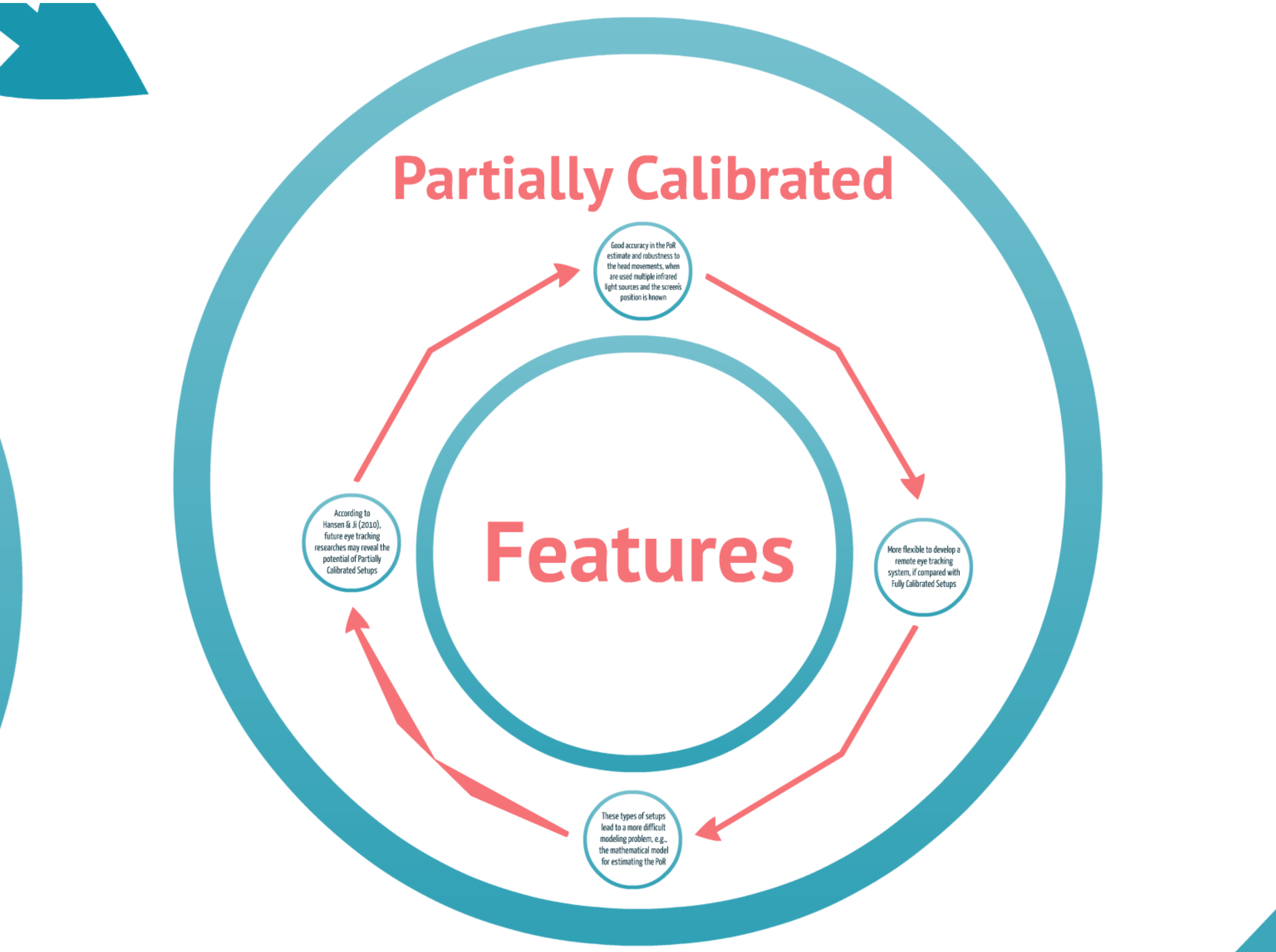

Partially Calibrated
Good accuracy in the PoR estimate and robustness to the head movements, when are used multiple infrared light sources and the screen's position is known
Features
More flexible to develop a remote eye tracking system, if compared with Fully Calibrated Setups
These types of setups lead to a more difficult modeling problem, e.g., the mathematical model for estimating the PoR
According to Hansen & Ji (2010), future eye tracking researches may reveal the potential of Partially Calibrated Setups

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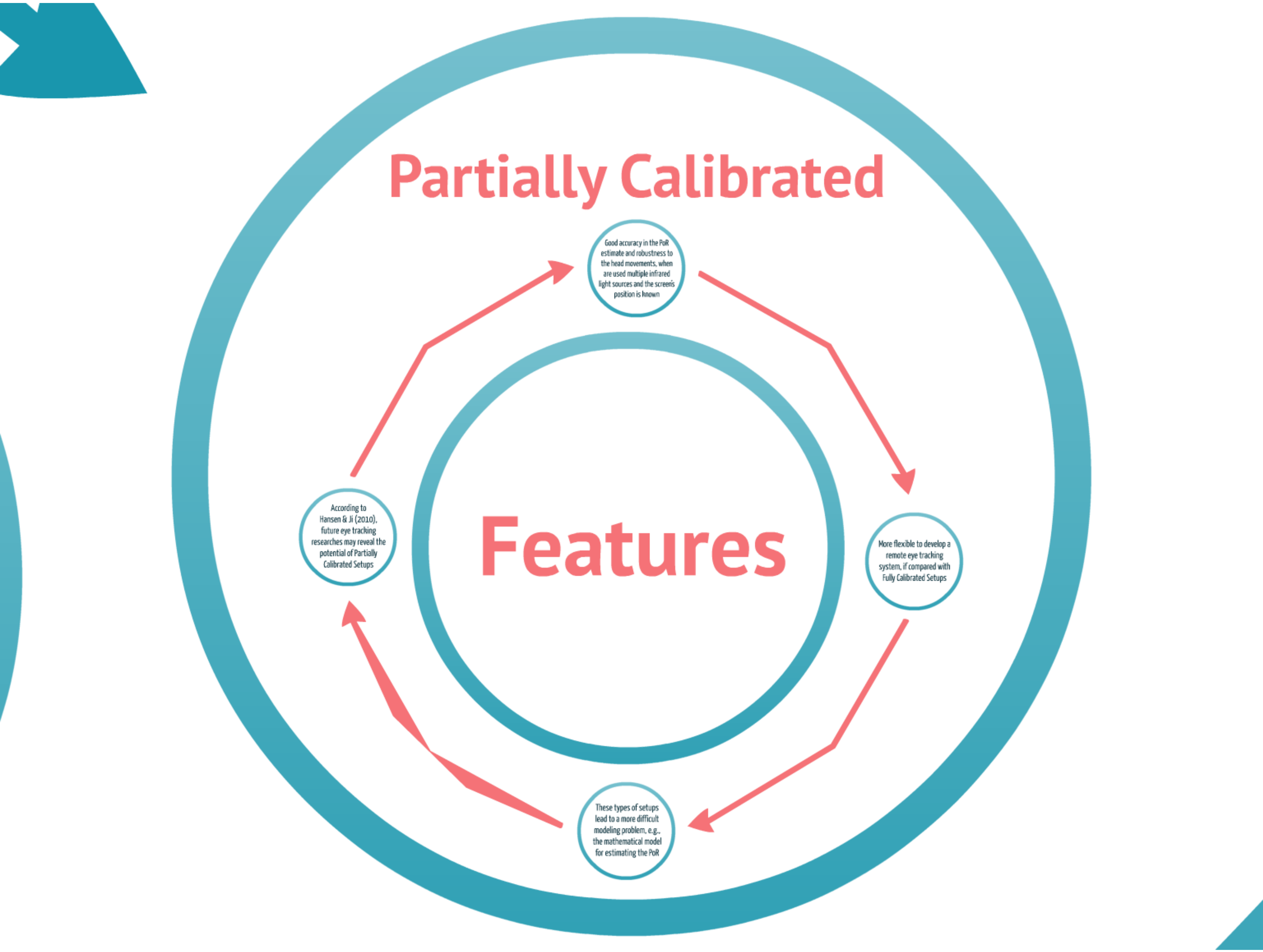

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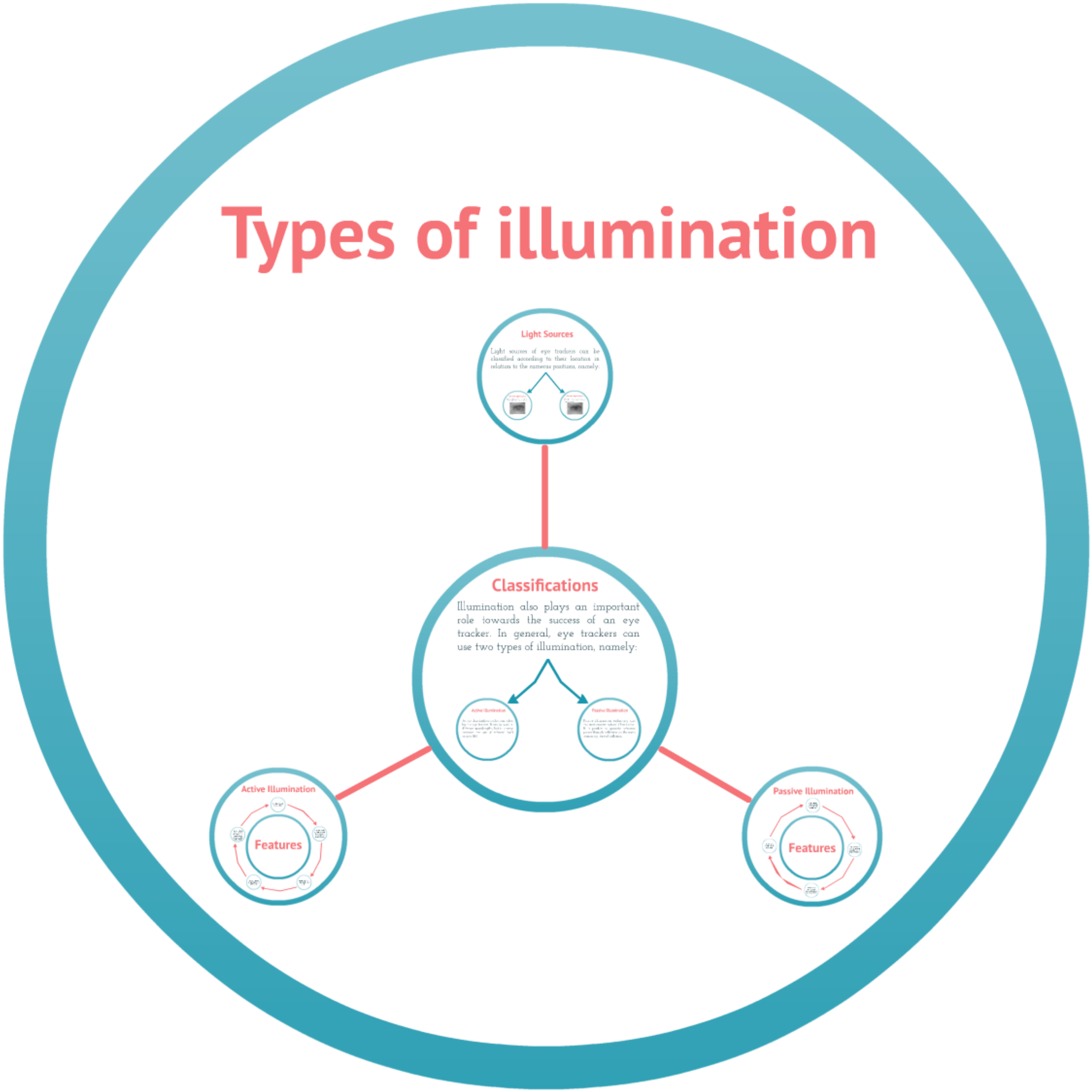
Good accuracy in the PoR estimate and robustness to the head movements, when are used multiple infrared light sources and the screen's position is known
More flexible to develop a remote eye tracking system, if compared with Fully Calibrated Setups
These types of setups lead to a more difficult modeling problem, e.g., the mathematical model for estimating the PoR
According to Hansen & Ji (2010), future eye tracking researches may reveal the potential of Partially Calibrated Setups
Features


Types of illumination
Light Sources
Light sources of eye trackers can be classified according to their location in relation to the cameras positions, namely:
Classifications
Illumination also plays an important role towards the success of an eye tracker. In general, eye trackers can use two types of illumination, namely:
Active Illumination
Features
Passive Illumination
Features

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Active Illumination

Active illumination is often controlled by the eye tracker. It can be used in different wavelengths, but it is very common the use of infrared light sources (IR)

Passive Illumination

Passive illumination exclusively uses the environment natural illumination. It is possible to generate reference points through reflexions on the user's cornea, e.g., screen's reflexion.

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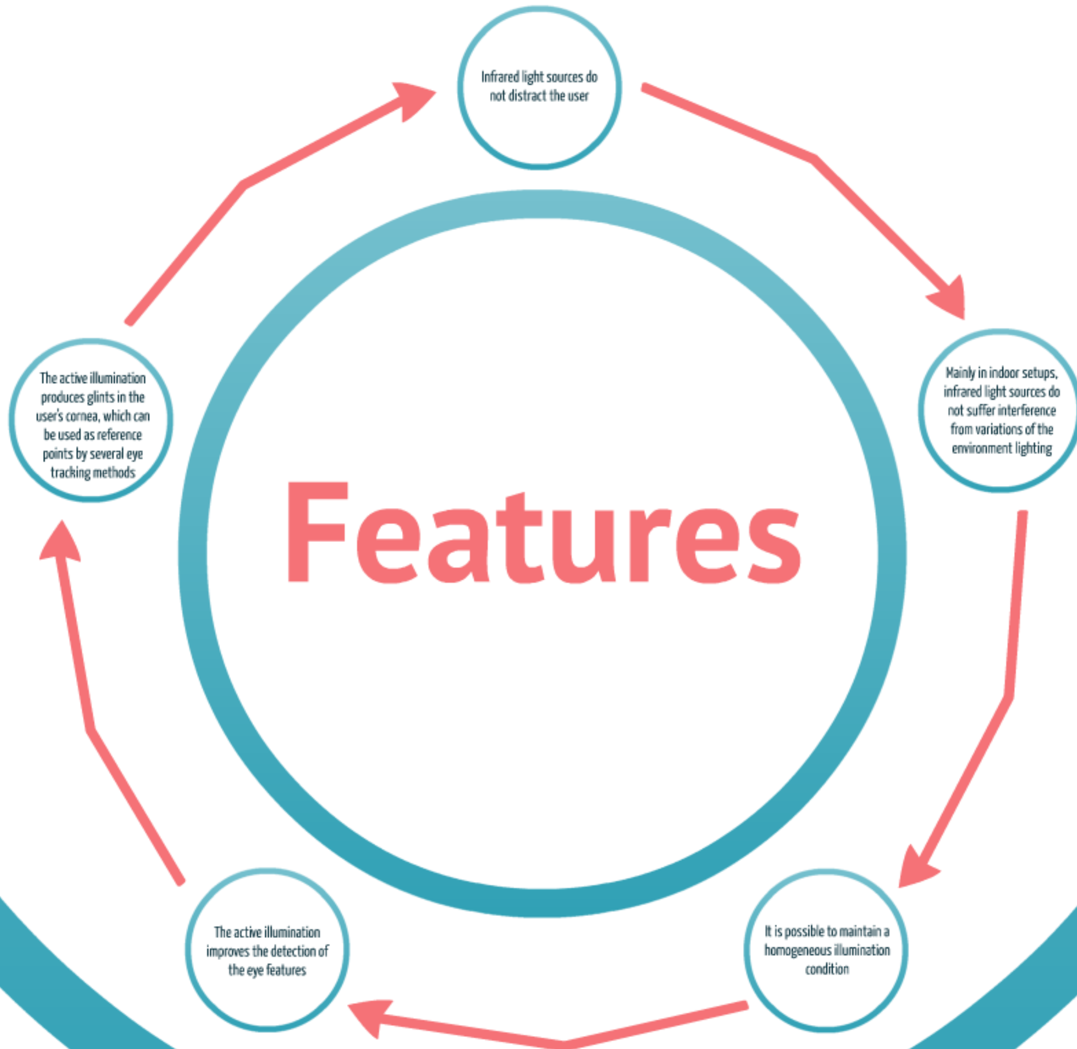
Active Illumination



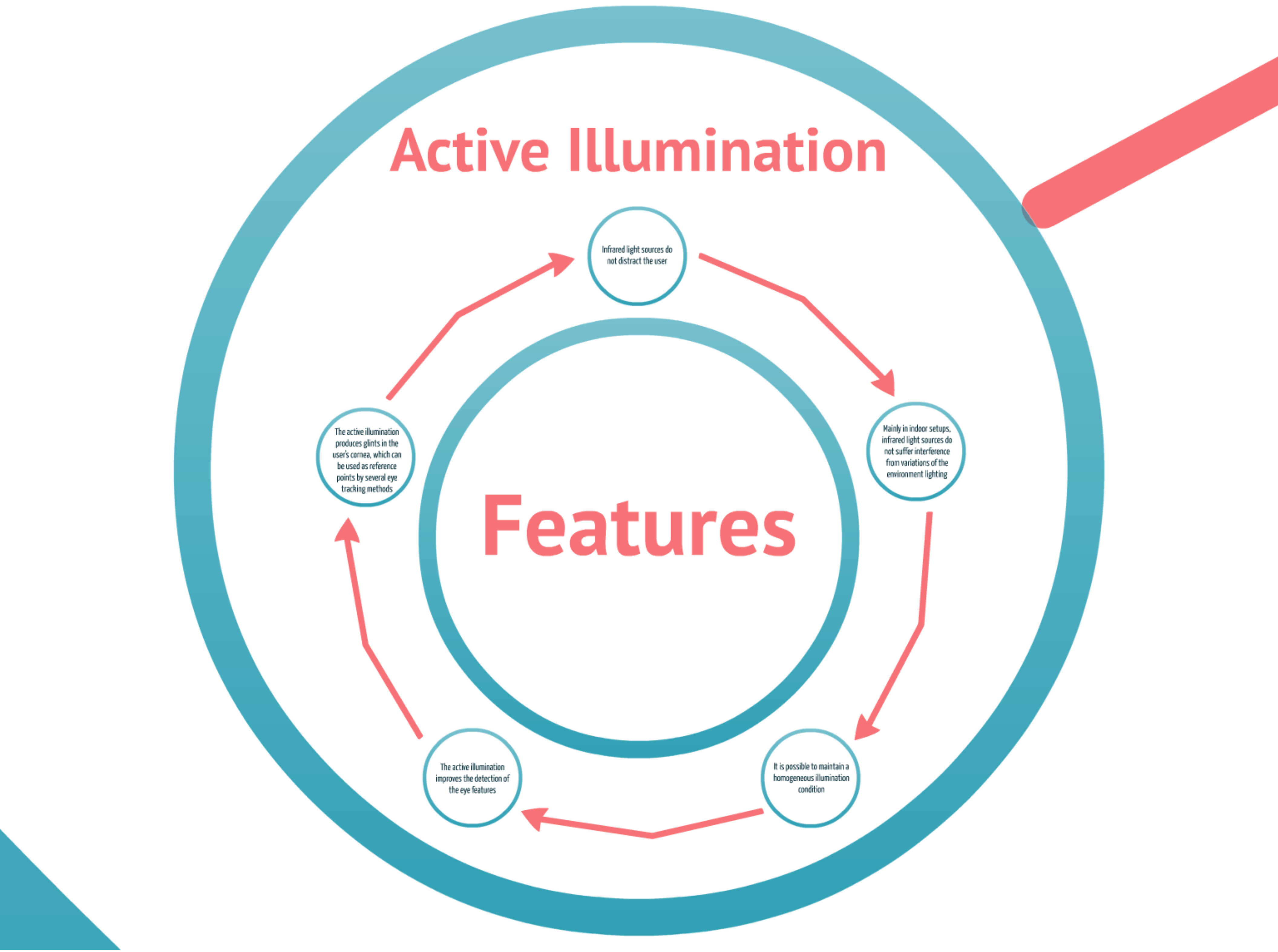
Infrared light sources do not distract the user

Mainly in indoor setups, infrared light sources do not suffer interference from variations of the environment lighting

It is possible to maintain a homogeneous illumination condition

The active illumination improves the detection of the eye features

The active illumination produces glints in the user's cornea, which can be used as reference points by several eye tracking methods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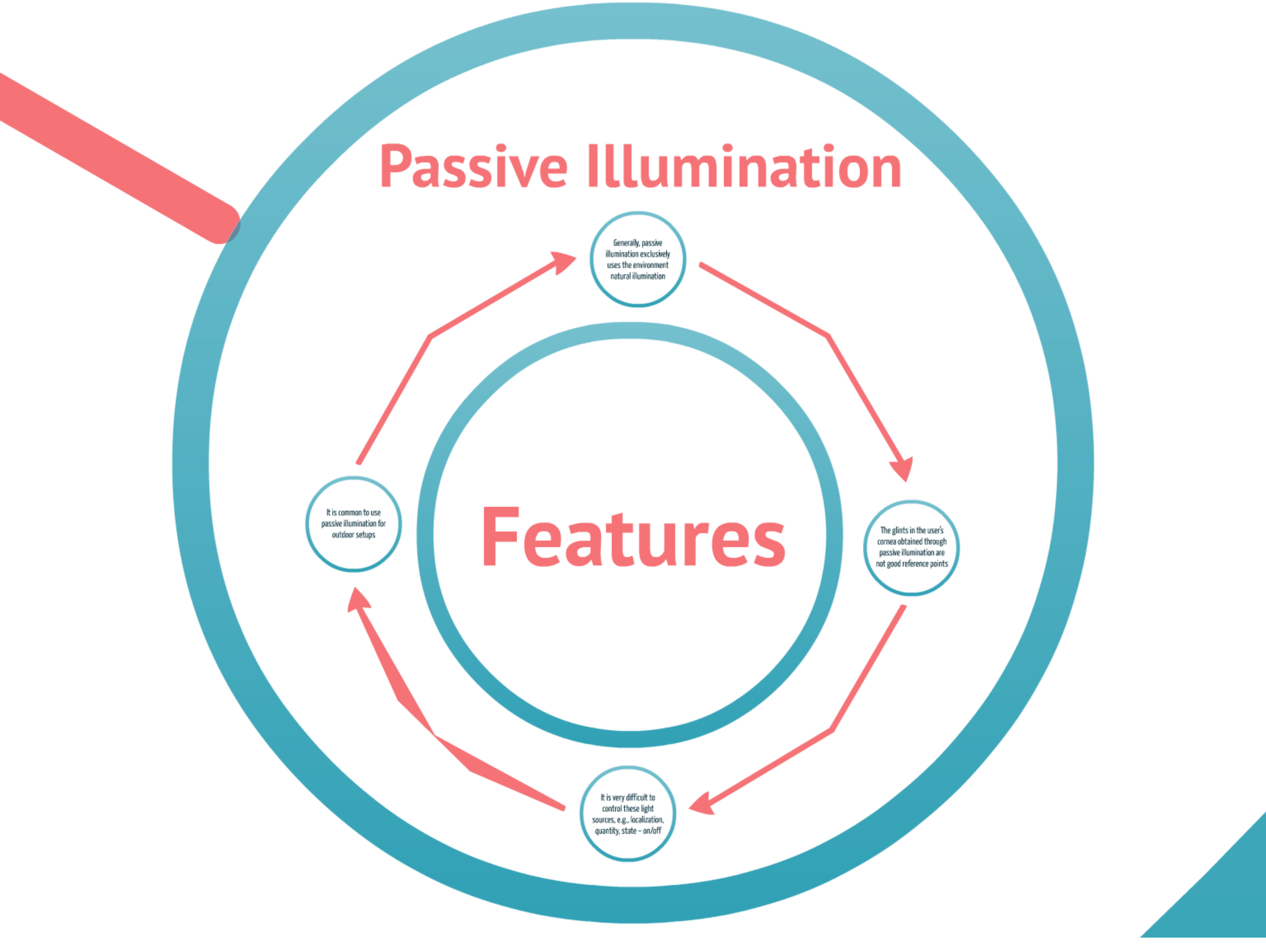
Passive Illumination
Features
Generally, passive illumination exclusively uses the environment natural illumination
The glints in the user's cornea obtained through passive illumination are not good reference points
It is very difficult to control these light sources, e.g., localization, quantity, state – on/off
It is common to use passive illumination for outdoor setups

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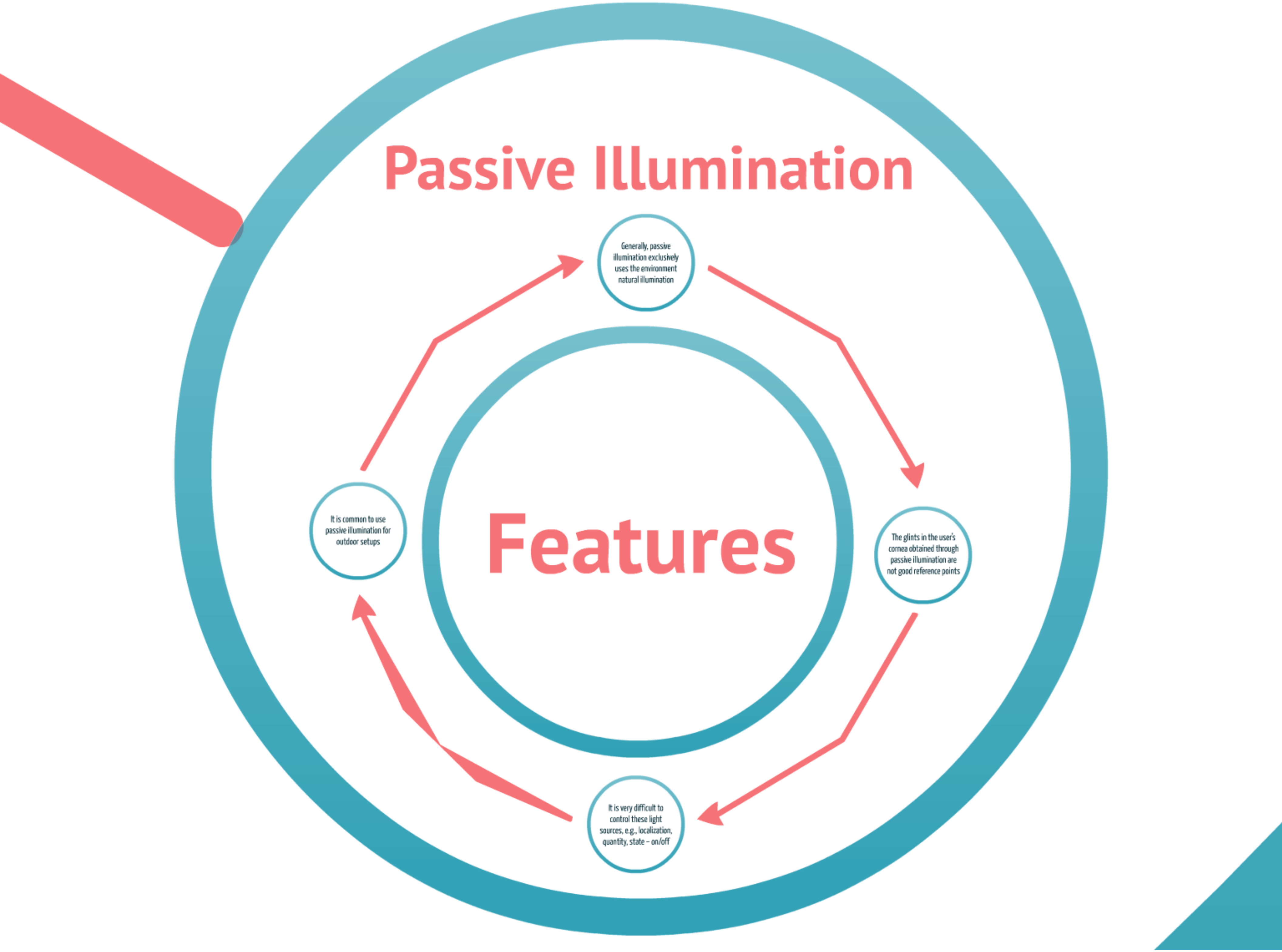
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Features

Light Sources

Light sources of eye trackers can be classified according to their location in relation to the cameras positions, namely:

On-axis light source

These type of illumination are placed in the camera optical axis (or very close to them)

Source: NARCIZO (2012)

Off-axis light source

These type of illumination are positioned in any other location different from the camera's optical axis

Source: NARCIZO (2012)

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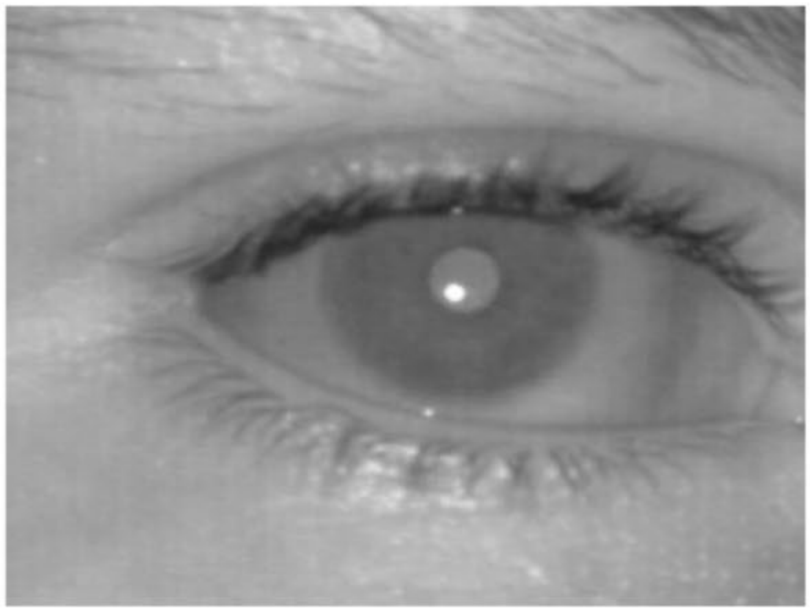

Source: NARCIZO (2012)

Off-axis light source

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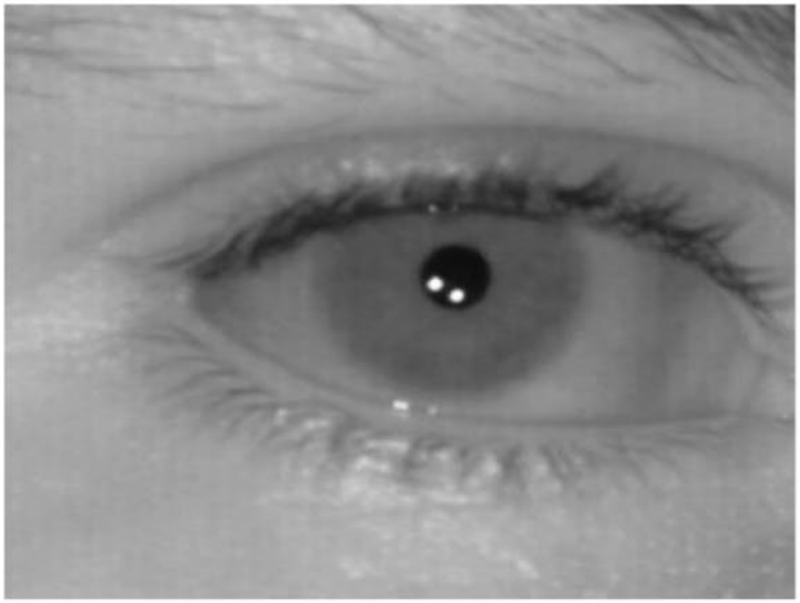
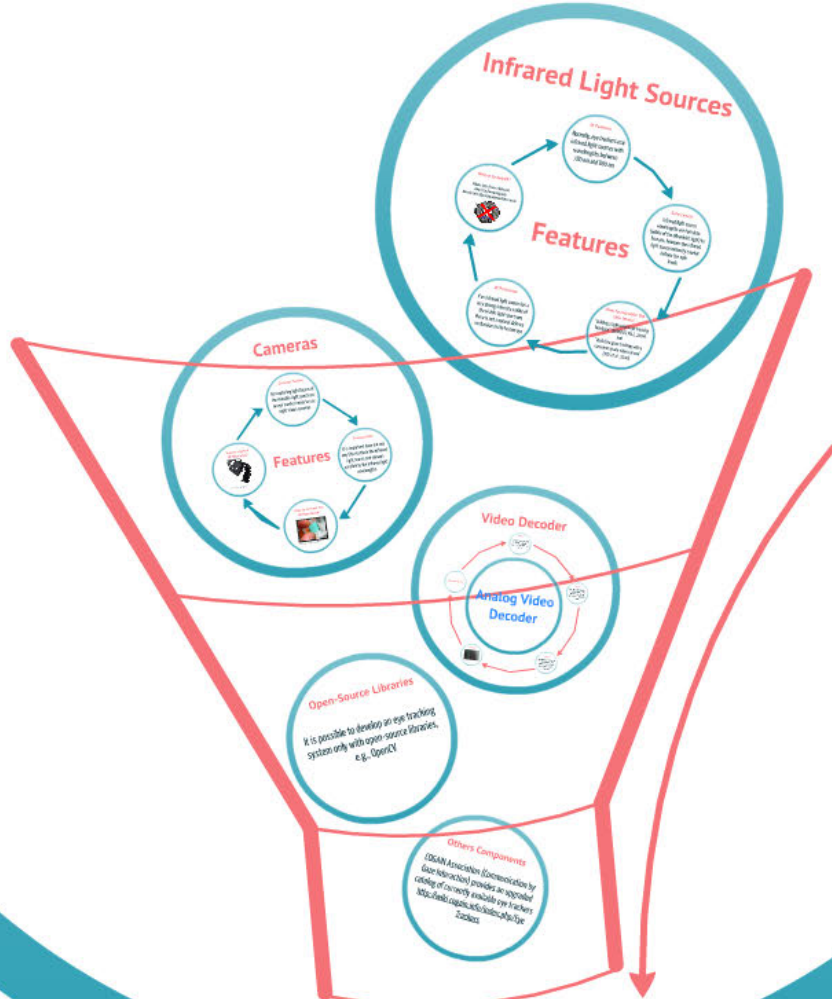
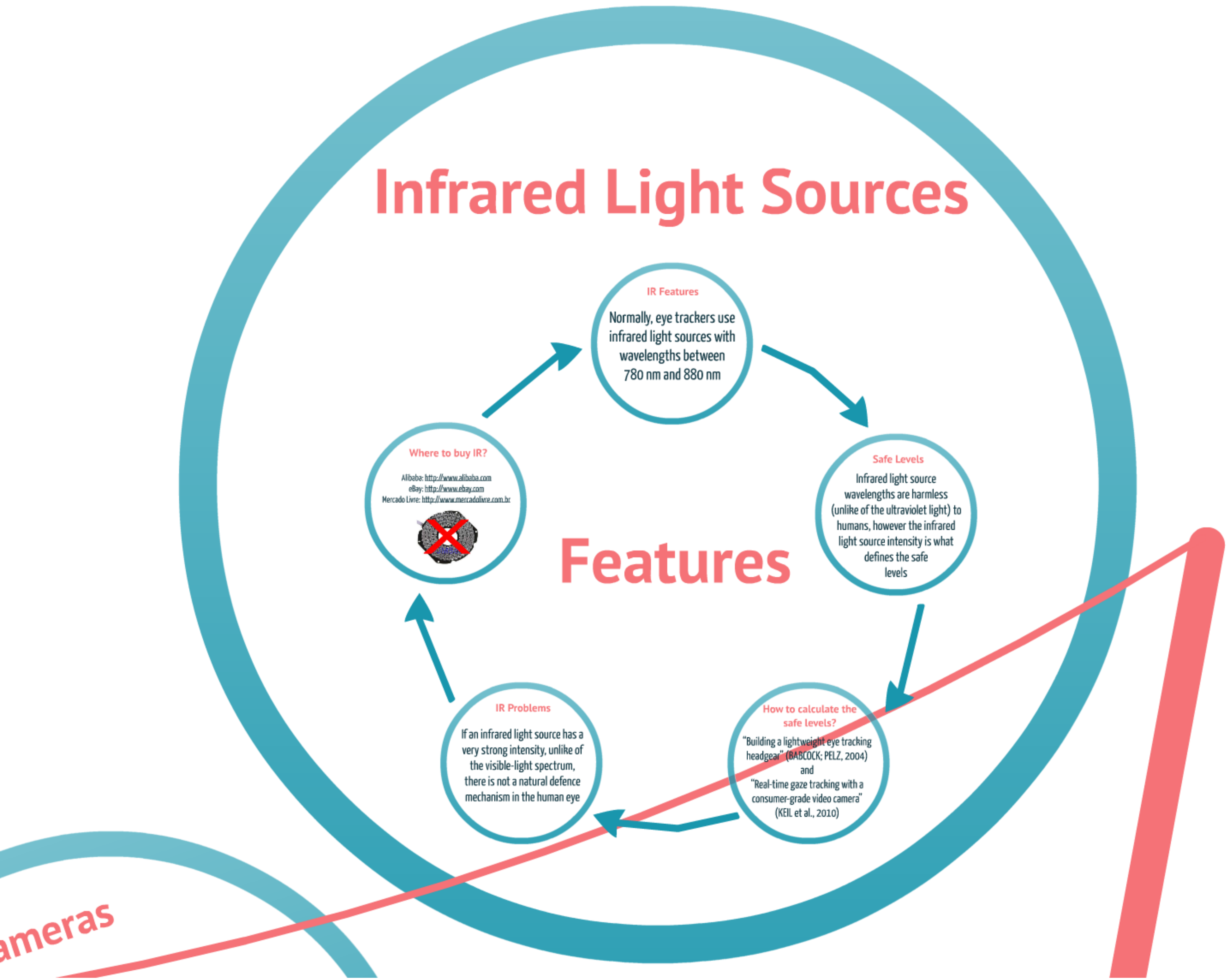


Source: NARCIZO (2012)

Hardware components





Infrared Light Sources
IR Features
Normally, eye trackers use infrared light sources with wavelengths between 780 nm and 880 nm
Safe Levels
Infrared light source wavelengths are harmless (unlike of the ultraviolet light) to humans, however the infrared light source intensity is what defines the safe levels
How to calculate the safe levels?
"Building a lightweight eye tracking headgear" (BABCOCK; PELZ, 2004)
and
"Real-time gaze tracking with a consumer-grade video camera" (KEIL et al., 2010)
IR Problems
If an infrared light source has a very strong intensity, unlike of the visible-light spectrum, there is not a natural defence mechanism in the human eye
Where to buy IR?
Alibaba: http://www.alibaba.com
eBay: http://www.ebay.com
Mercado Livre: http://www.mercadolivre.com.br
Features
ameras

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Cameras

Cameras' Sensor

For capturing light beams of the invisible-light spectrum, an eye tracker needs to use night vision cameras

Prerequisites

It is important does not use any filter to block the infrared light beams and sensors sensible to the infrared light wavelengths

How to remove the IR filter block?

Source: http://goo.gl/zSTk6r

How to create a IR filter pass?

Source: http://goo.gl/8lgbeu

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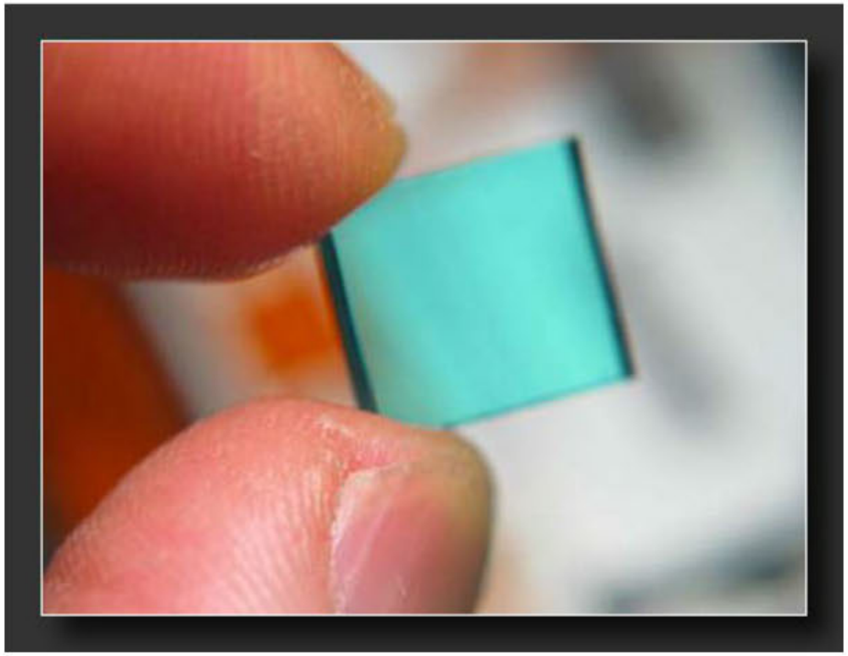
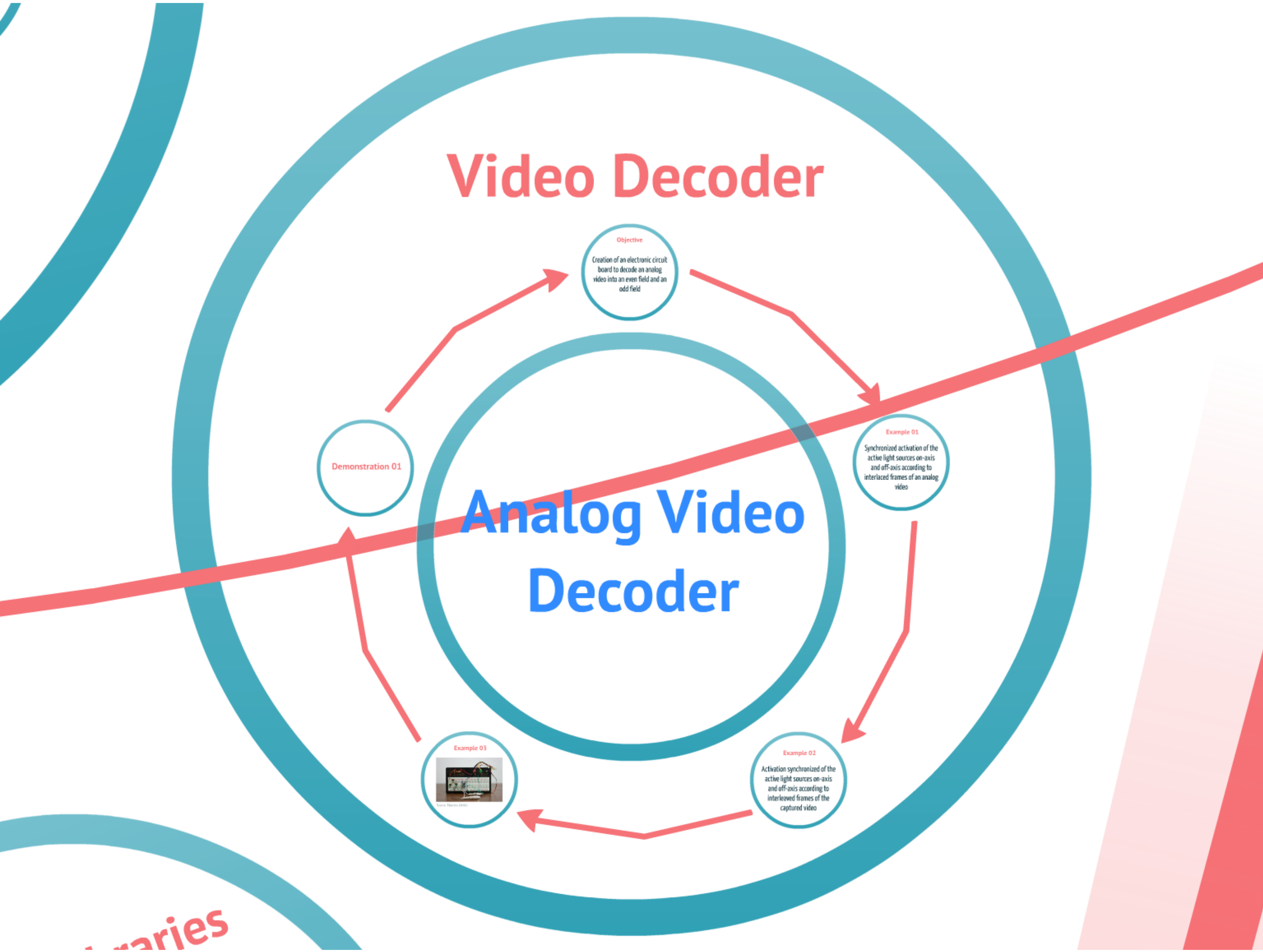


Source: http://goo.gl/zSTk6r

How to create a IR filter pass?

Source: http://goo.gl/Hgbesj


Video Decoder
Objective
Creation of an electronic circuit board to decode an analog video into an even field and an odd field
Example 01
Synchronized activation of the active light sources on-axis and off-axis according to interlaced frames of an analog video
Example 02
Activation synchronized of the active light sources on-axis and off-axis according to interleaved frames of the captured video
Example 03
Demonstration 01
Analog Video Decoder

Objective

Creation of an electronic circuit board to decode an analog video into an even field and an odd field

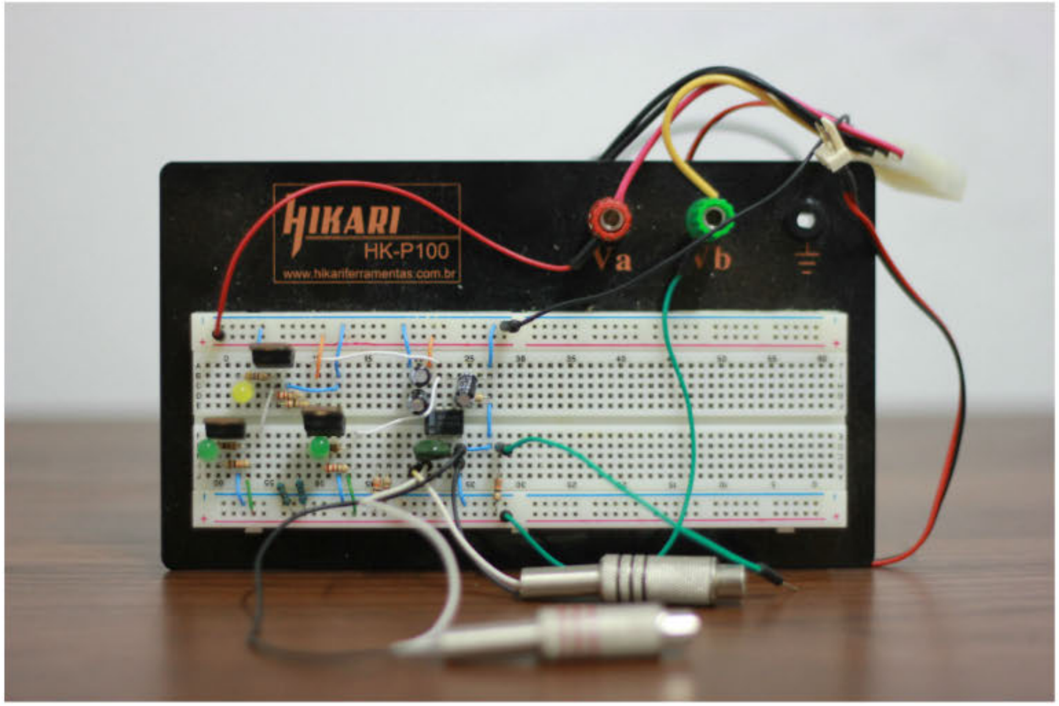
Example 01

Synchronized activation of the active light sources on-axis and off-axis according to interlaced frames of an analog video

Example 02

Activation synchronized of the active light sources on-axis and off-axis according to interleaved frames of the captured video

Example 03



Source: Narcizo (2012)

Demonstration 01

Open-Source Libraries

It is possible to develop an eye tracking system only with open-source libraries, e.g., OpenCV

Others Components

COGAIN Association (Communication by Gaze Interaction) provides an upgraded catalog of currently available eye trackers http://wiki.cogain.info/index.php/Eye Trackers

Calibration process from the device's side

When is it necessary to perform this calibration?

Calibration from the device's side is a process necessary for adjusting the hardware components used by a fully or partially calibrated eye tracker

Most fully calibrated eye trackers use stereo cameras

The first step is to align correctly the cameras optical axes

The calibration of eye tracker components can be performed through MATLAB Camera Calibration Toolbox

Example of Calibration Process

Another possibility is using the OpenCV Library nother possibility is using the OpenCV Library

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Example of Calibration Process

The calibration of eye

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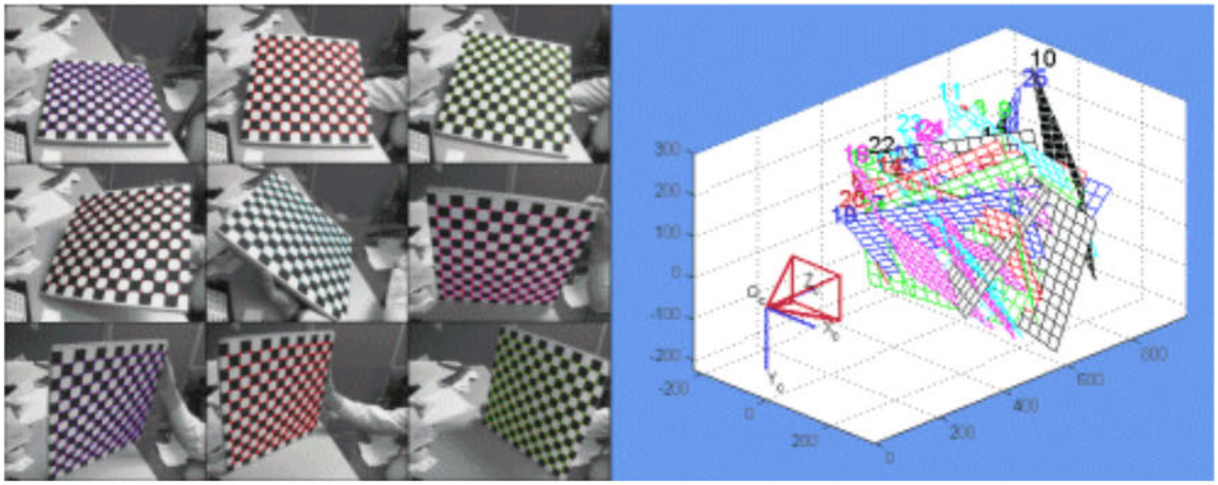
Example of Calibration Process

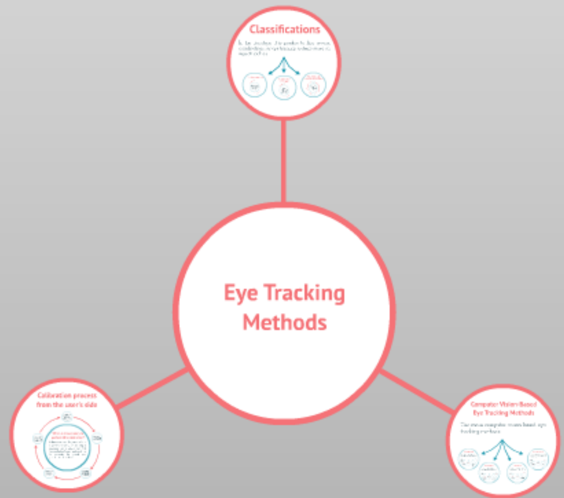


Source: http://goo.gl/mqOs39

Another possibility is using the OpenCV Library

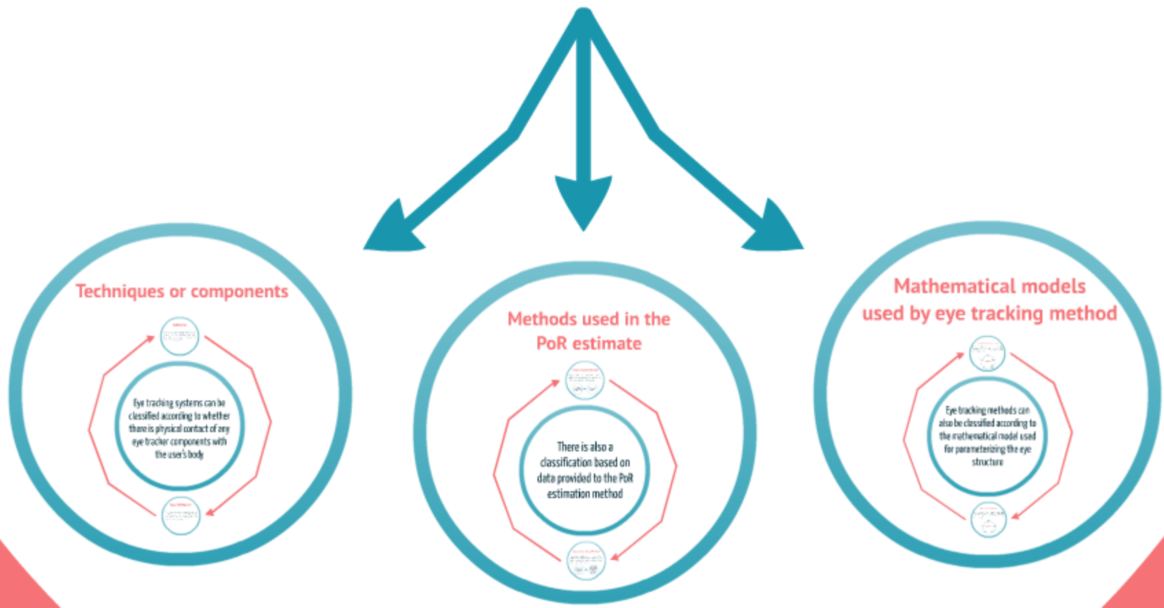
Eye Tracking Methods

Presentation of the main computer-vision-based eye tracking methods

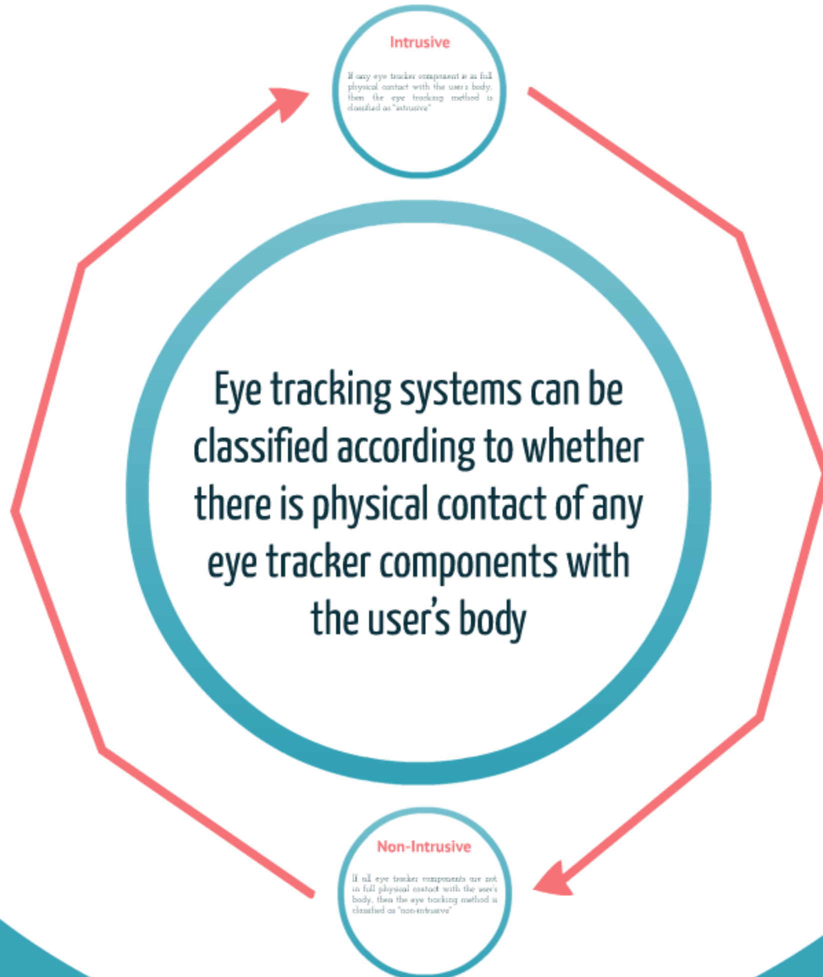


Classifications

In the literature, it is possible to find several classifications for eye tracking systems based on aspects such as:



Techniques or components

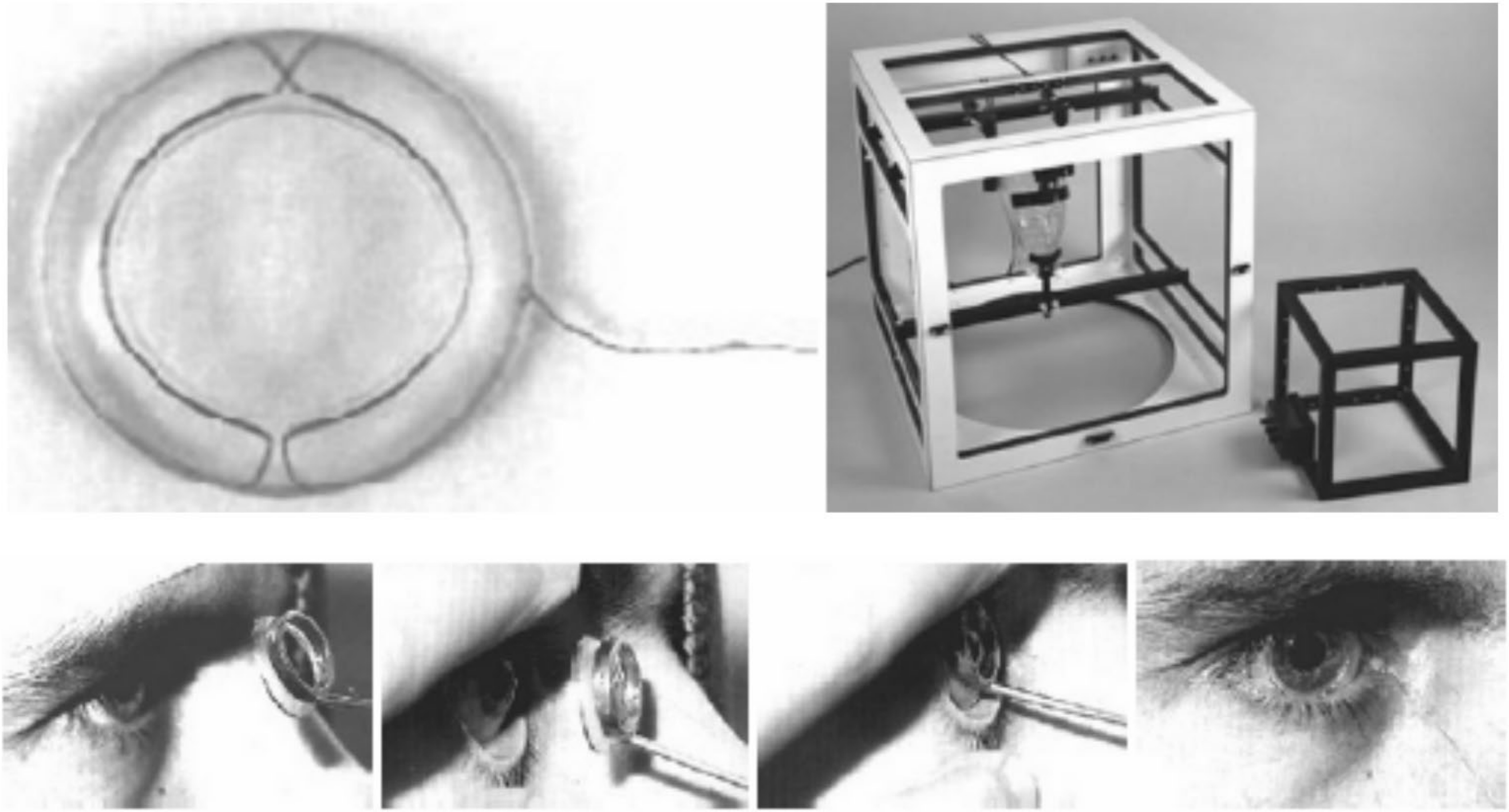


Eye tracking systems can be classified according to whether there is physical contact of any eye tracker components with the user's body

Intrusive

If any eye tracker component is in full physical contact with the user's body, then the eye tracking method is classified as "intrusive"

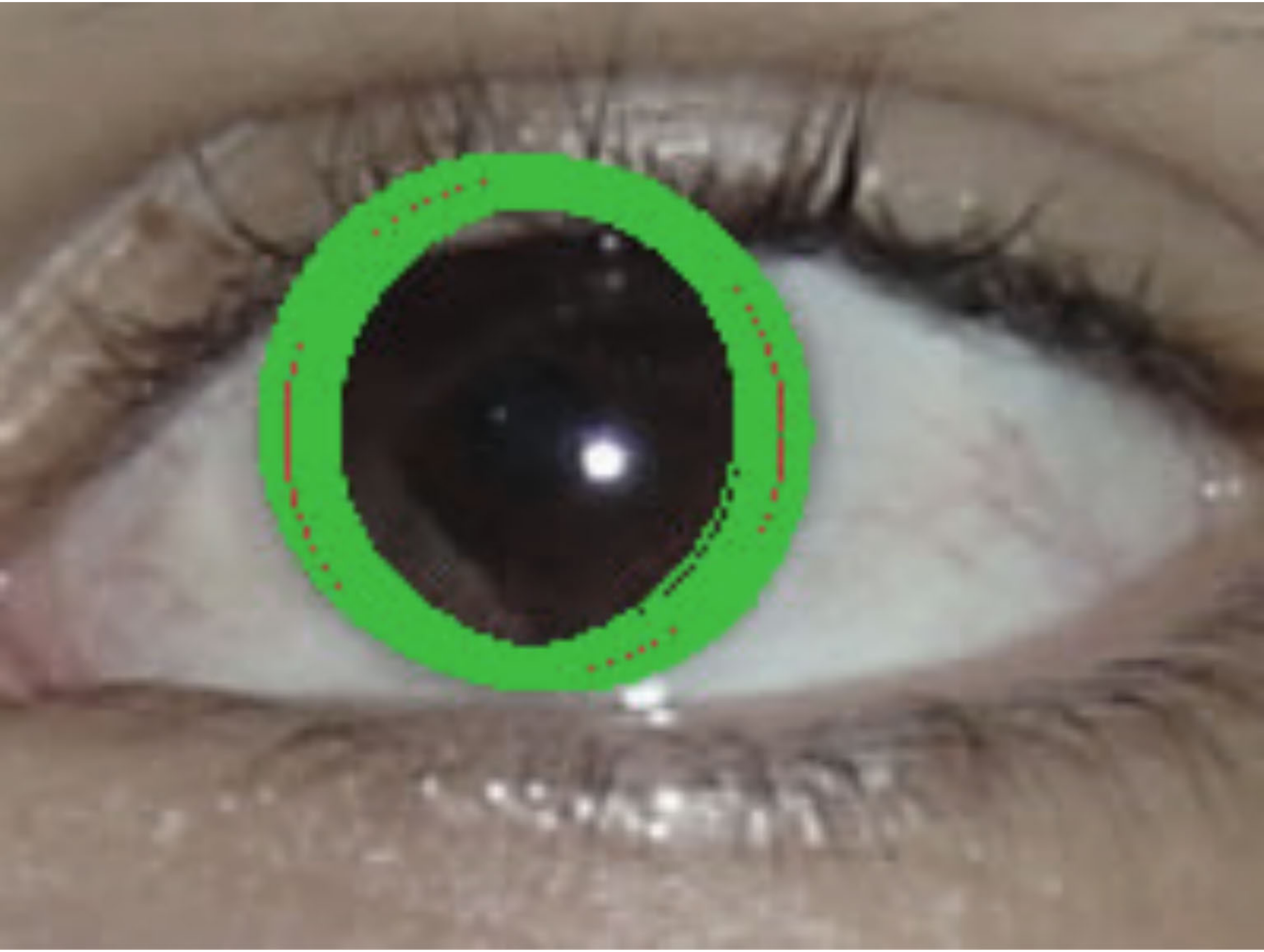
Source: DUCHOWSKI (2007)

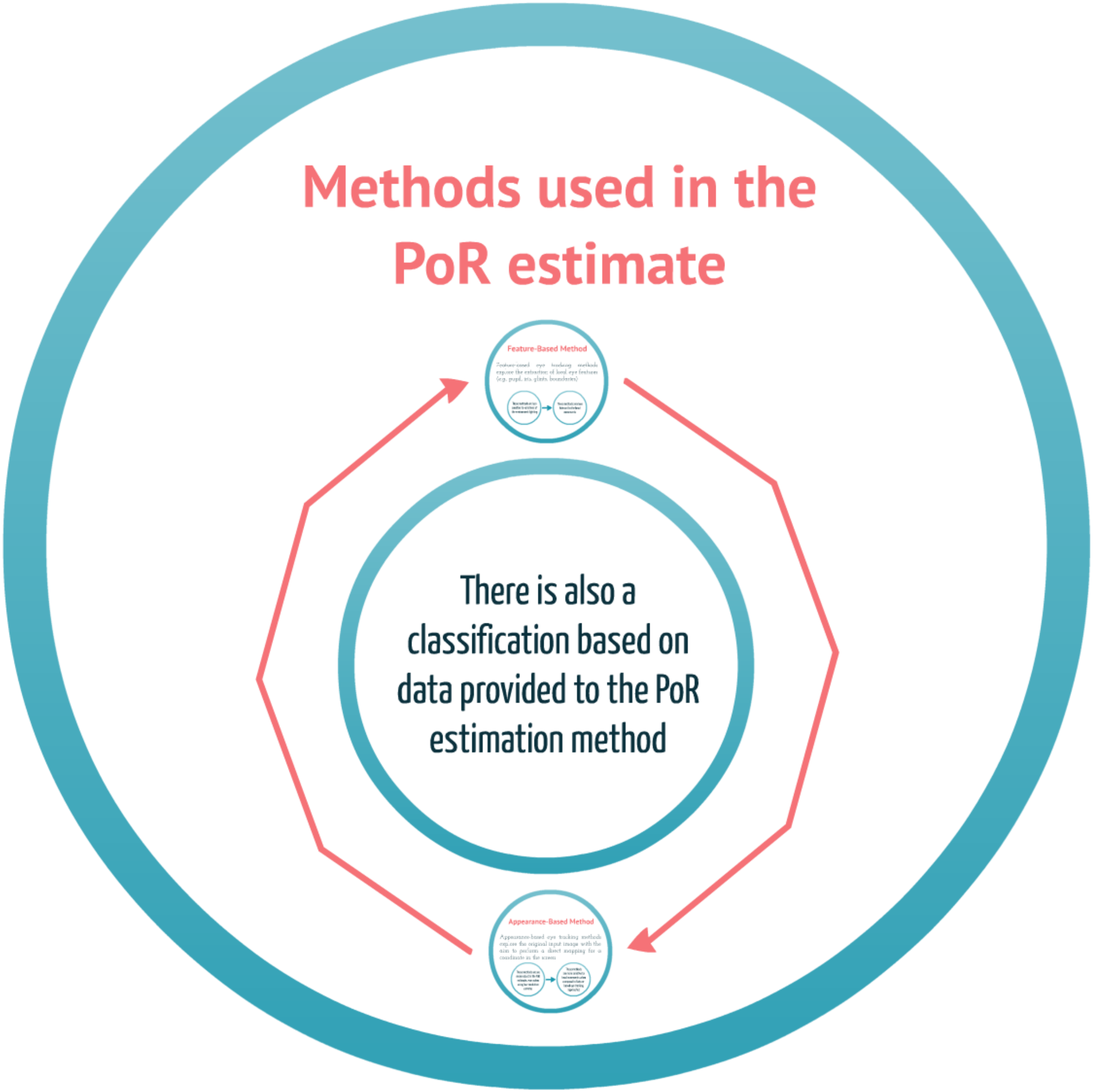


Source: DUCHOWSKI (2007)

Non-Intrusive

If all eye tracker components are not in full physical contact with the user's body, then the eye tracking method is classified as "non-intrusive"




Methods used in the PoR estimate
Feature-Based Method
Feature-based eye tracking methods explore the extraction of local eye features (e.g. pupil, iris, glints, boundaries)
There is also a classification based on data provided to the PoR estimation method
Appearance-Based Method
Appearance-based eye tracking methods exploit the original input image with the aim to perform a direct mapping for a coordinate in the screen

There is also a classification based on data provided to the PoR estimation method

Feature-Based Method

Feature-based eye tracking methods explore the extraction of local eye features (e.g., pupil, iris, glints, boundaries)

These methods are less sensitive to variations of the environment lighting → These methods are more tolerant to the head movements

These methods are less sensitive to variations of the environment lighting

These methods are more tolerant to the head movements

Appearance-Based Method

Appearance-based eye tracking methods explore the original input image with the aim to perform a direct mapping for a coordinate in the screen

These methods are are more robust in the PoR estimate, even when using low-resolution cameras

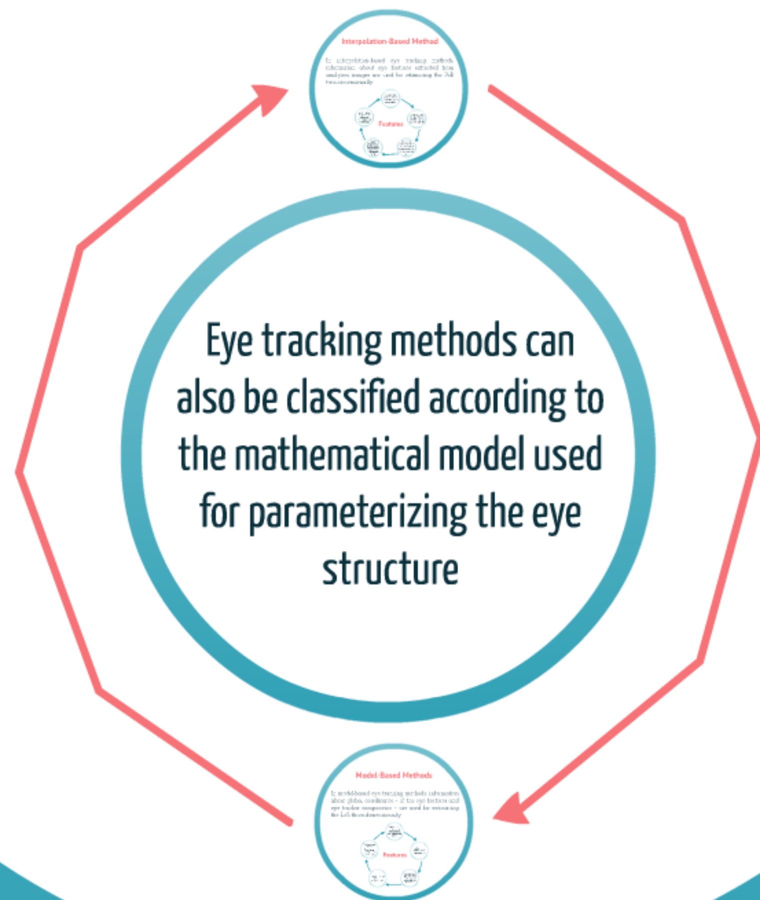
→

These methods are more sensitive to head movements when compared to feature-based eye tracking approaches

These methods are are more robust in the PoR estimate, even when using low-resolution cameras

These methods are more sensitive to head movements when compared to feature-based eye tracking approaches

Mathematical models used by eye tracking method



Eye tracking methods can also be classified according to the mathematical model used for parameterizing the eye structure

Interpolation-Based Method

In interpolation-based eye tracking methods, information about eye features extracted from analyzed images are used for estimating the PoR two-dimensionally

These methods are popular due to their relative simplicity and accuracy achieved

Interpolation-based methods estimate the user's PoR over a plane, i.e., two-dimensionally

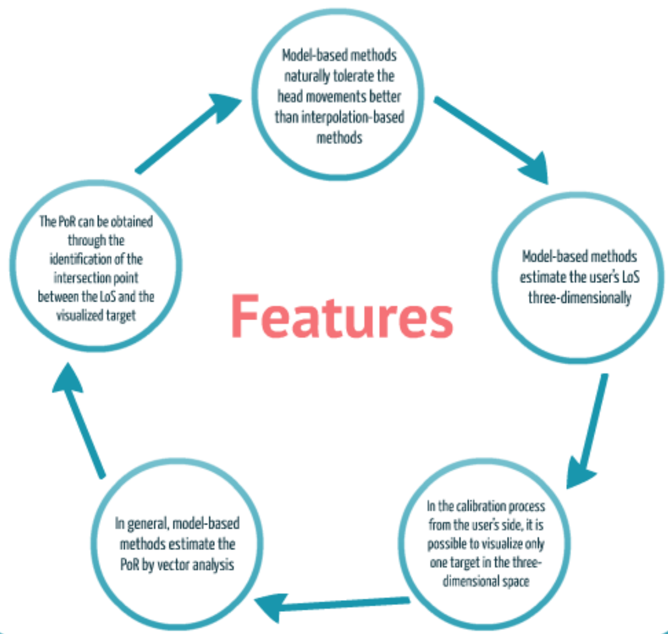
In the calibration process from the user's side, it is necessary to visualize several targets in the two-dimensional space

A mapping function is used as a decoder to identify the relationship between eye features extracted from input images and the PoR estimate

One of the problems of this approach is the sensitivity of its mapping function to the head movements

Model-Based Methods

In model-based eye tracking methods, information about global coordinates – of the eye features and eye tracker components – are used for estimating the LoS three-dimensionally



Model-based methods naturally tolerate the head movements better than interpolation-based methods

Model-based methods estimate the user's LoS three-dimensionally

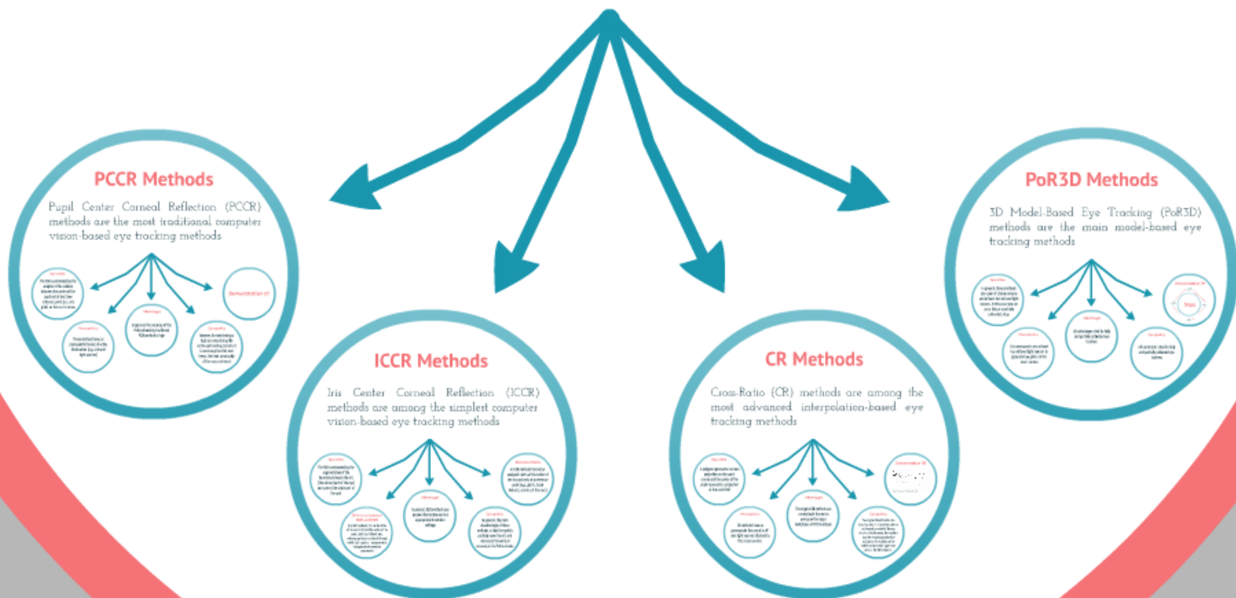
In the calibration process from the user's side, it is possible to visualize only one target in the three-dimensional space

In general, model-based methods estimate the PoR by vector analysis

The PoR can be obtained through the identification of the intersection point between the LoS and the visualized target

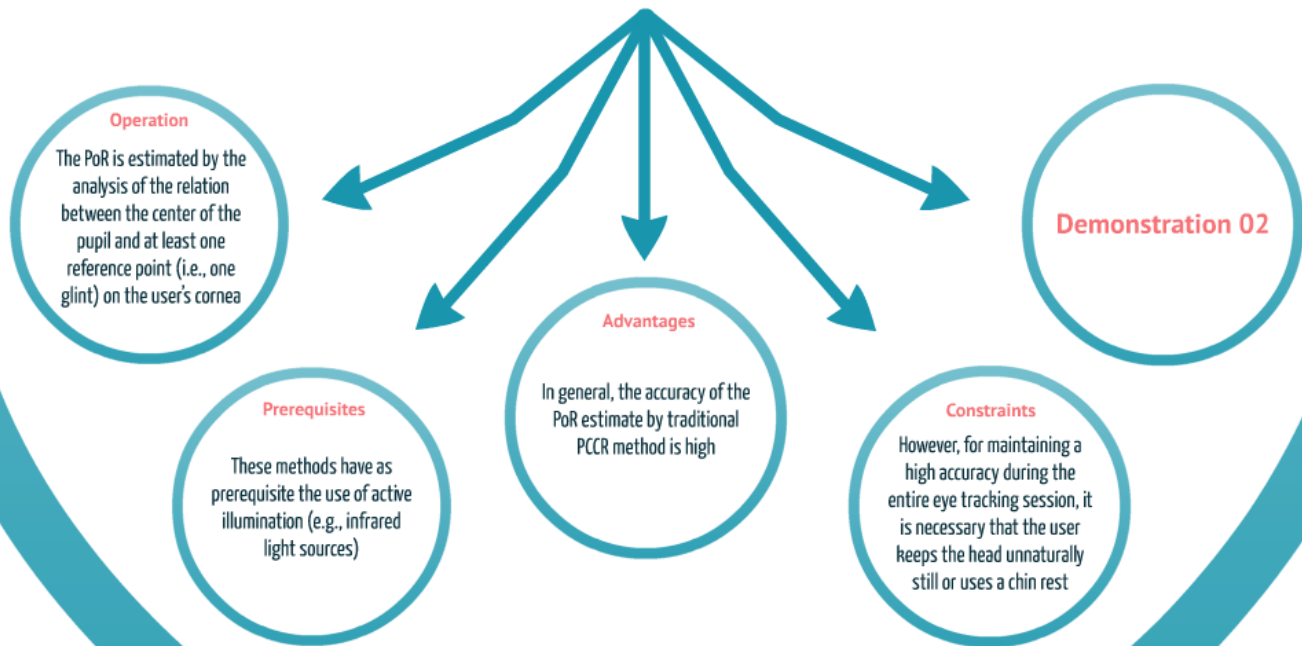
Computer Vision-Based Eye Tracking Methods

The main computer vision-based eye tracking methods:



PCCR Methods

Pupil Center Corneal Reflection (PCCR) methods are the most traditional computer vision-based eye tracking methods



Iris

Operation

The PoR is estimated by the analysis of the relation between the center of the pupil and at least one reference point (i.e., one glint) on the user's cornea

Prerequisites

These methods have as prerequisite the use of active illumination (e.g., infrared light sources)

Advantages

In general, the accuracy of the PoR estimate by traditional PCCR method is high

Constraints

However, for maintaining a high accuracy during the entire eye tracking session, it is necessary that the user keeps the head unnaturally still or uses a chin rest

Demonstration 02

ICCR Methods

Iris Center Corneal Reflection (ICCR) methods are among the simplest computer vision-based eye tracking methods

Operation

The PoR is estimated by the segmentation of the boundary between the iris (the colored part of the eye) and sclera (the white part of the eye)

Differences between ICCR and PCCR

(i) in ICCR methods, the center of the iris is used instead of the center of the pupil; and (ii) in ICCR methods, reference points are obtained through visible-light spectrum components or through active illumination components

Advantages

In general, ICCR methods use passive illumination and are appropriate to outdoor settings

Constraints

In general, the main disadvantage of these methods is that the eyelids partially cover the iris and decreases the vertical accuracy in the PoR estimate

Reference Points

In ICCR methods the vector analyzed starts at the center of the iris and ends at a reference point (e.g., glints, facial features, corners of the eyes)

Operation

The PoR is estimated by the segmentation of the boundary between the iris (the colored part of the eye) and sclera (the white part of the eye)

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CR Methods

Cross-Ratio (CR) methods are among the most advanced interpolation-based eye tracking methods

Operation

A polygon represents a screen projection on the user's cornea and the center of the pupil represents a projection of the user's PoR

Prerequisites

CR methods have as prerequisite the use of 4 off-axis light sources attached to the screen corners

Advantages

The original CR method was created with the aim to overcome the major limitations of PCCR methods

Constraints

The original CR method has low accuracy, once it is based on a simple mathematical model of the eye structure. Furthermore, this model is sensitive to noise produced by occlusions of the glints by the eyelids and presents high errors rates in the PoR estimate.

Demonstration 03

Source: Coutinho & Morimoto (2012)

use a fully or a partially calibrated setup

Operation

A polygon represents a screen projection on the user's cornea and the center of the pupil represents a projection of the user's PoR

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The original CR method was created with the aim to overcome the major limitations of PCCR methods

Constraints

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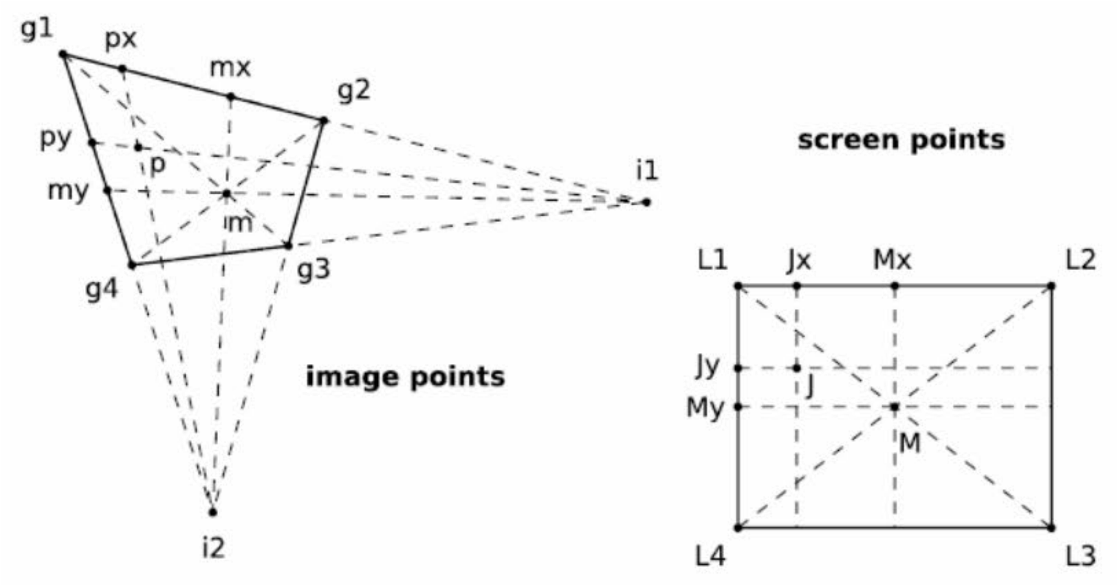
Demonstration 03



Source: Coutinho & Morimoto (2012)

PoR3D Methods

3D Model-Based Eye Tracking (PoR3D) methods are the main model-based eye tracking methods

Operation

In general, these methods use a pair of stereo cameras and at least two infrared light sources. In this case, you can use a fully or a partially calibrated setup

Prerequisites

It is necessary to use at least two infrared light sources to generate two glints on the user's cornea

Advantages

All advantages cited for fully and partially calibrated eye trackers

Constraints

All constraints cited for fully and partially calibrated eye trackers

Demonstration 04

ng the
d eye

Operation

In general, these methods use a pair of stereo cameras and at least two infrared light sources. In this case, you can use a fully or a partially calibrated setup

Prerequisites

It is necessary to use at least two infrared light sources to generate two glints on the user's cornea

Advantages

All advantages cited for fully and partially calibrated eye trackers

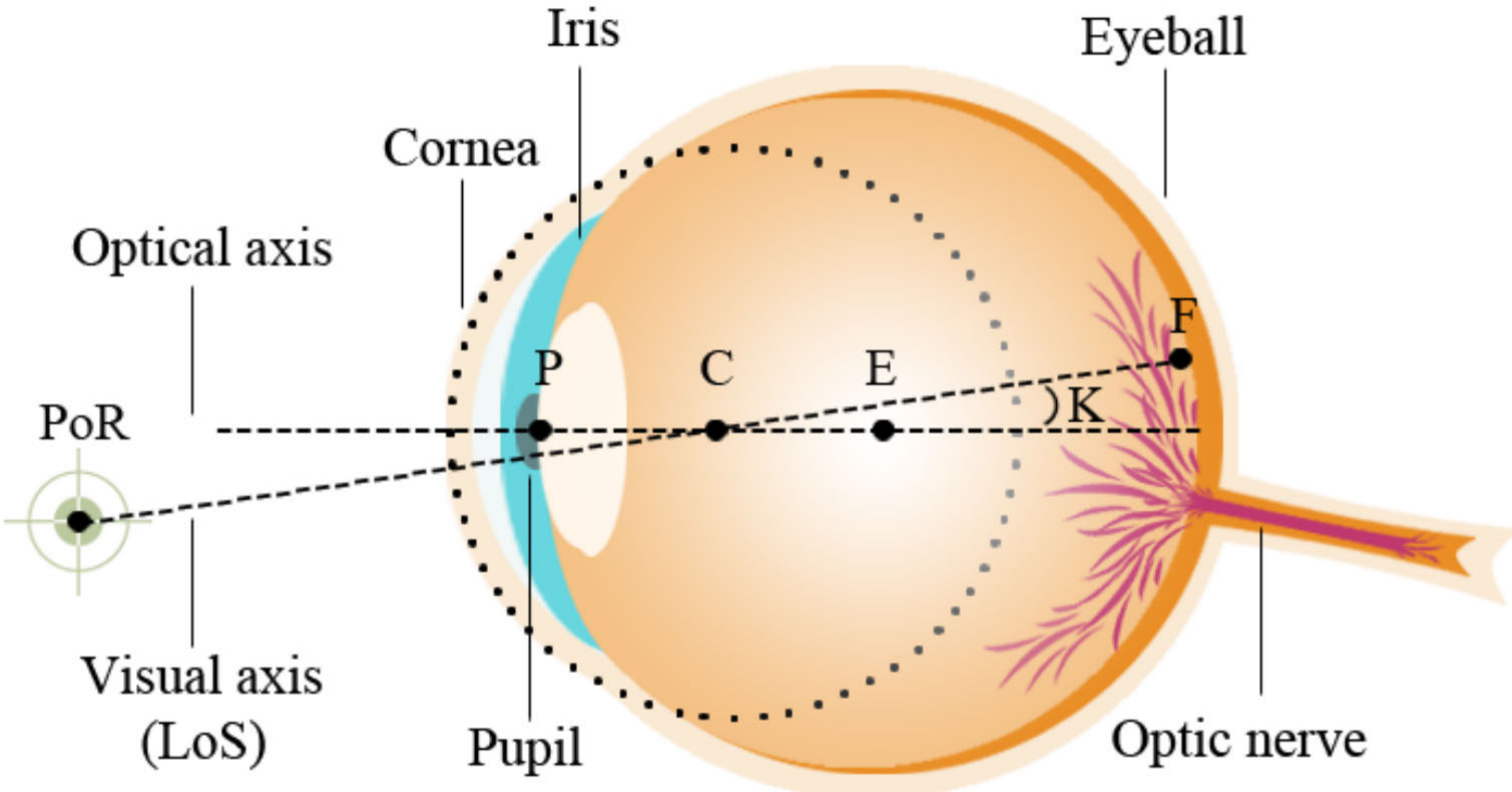
Constraints

All constraints cited for fully and partially calibrated eye trackers

Demonstration 04

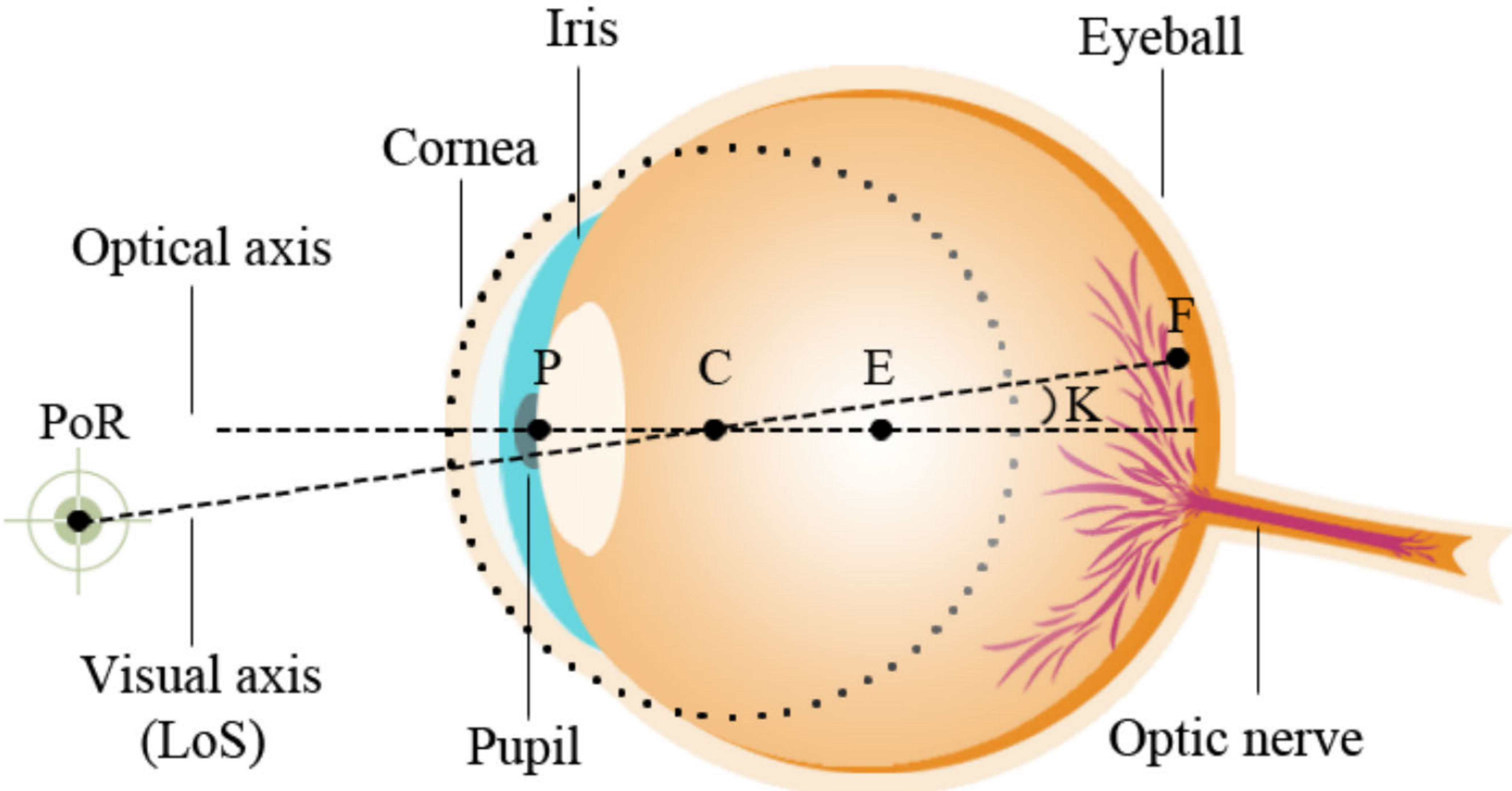
Step 01:
The detection of the spherical center of the cornea (see the C point)

of the human visual system

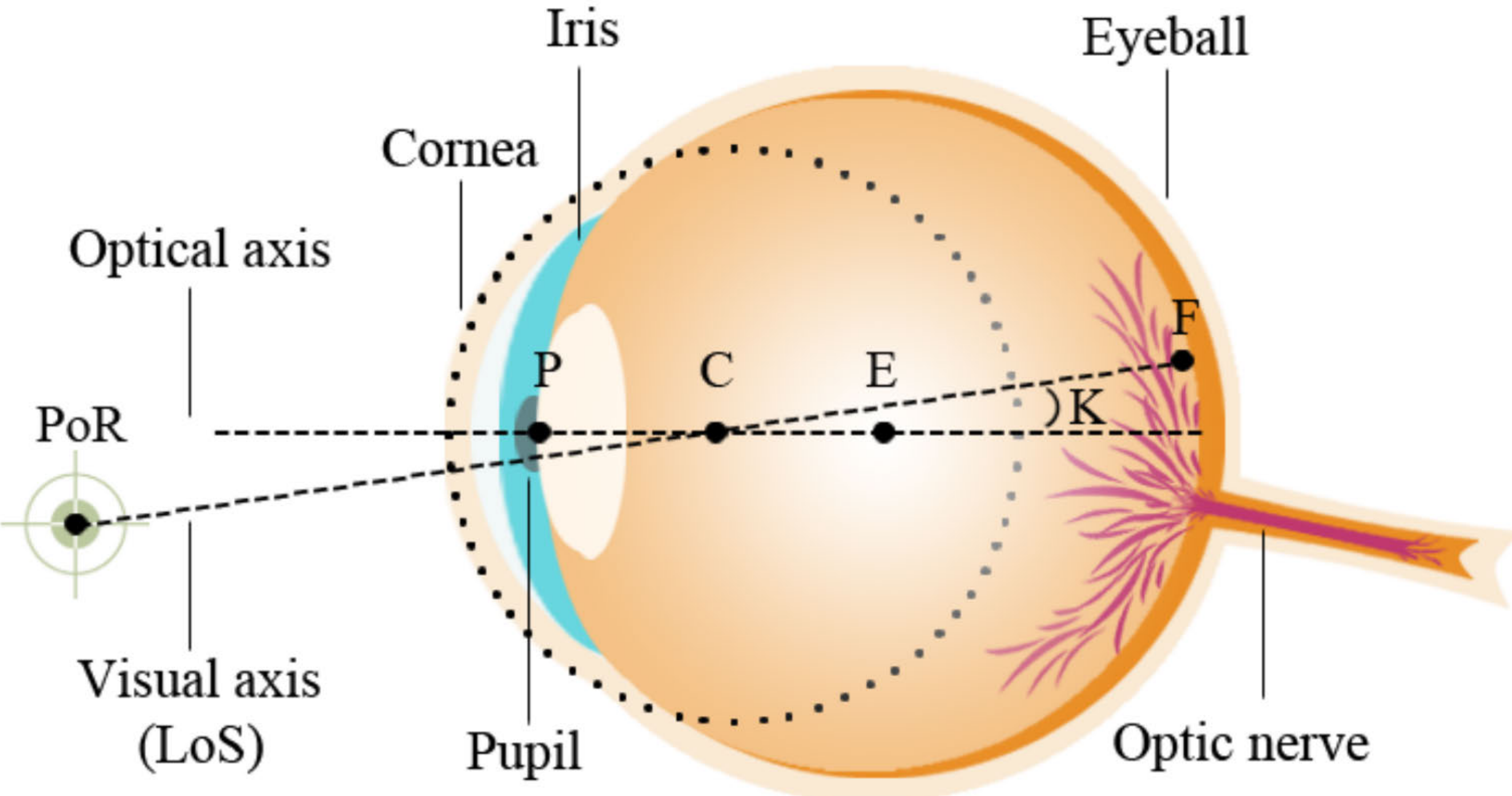


Step 02:
The estimate of the eye's optical axis

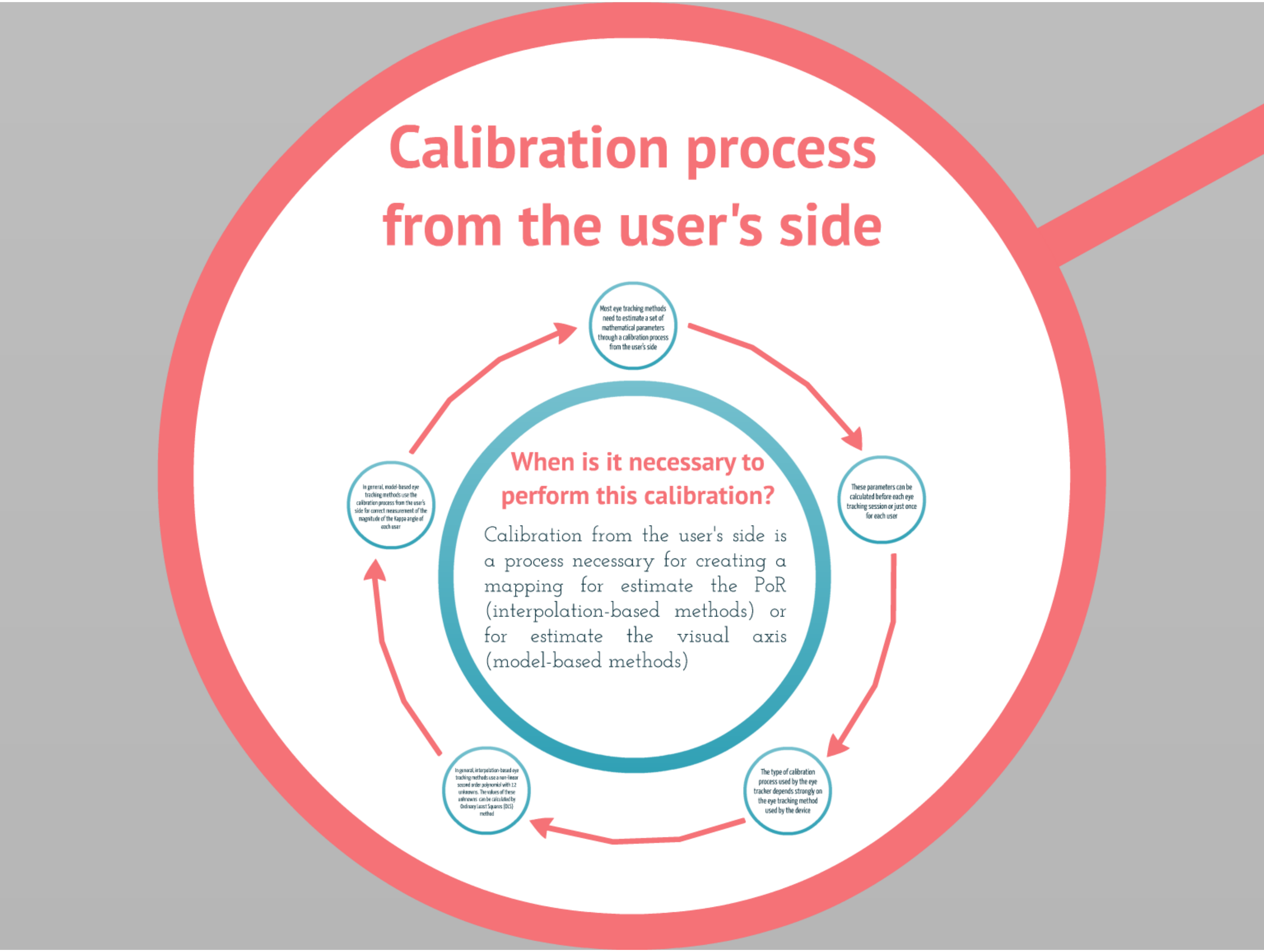
of the human visual system



Step 03:
The estimate of the eye's visual axis


Iris
Eyeball
Cornea
Optical axis
F
P
C
E
K
PoR
Visual axis
(LoS)
Pupil
Optic nerve

Step 04:
The estimate of the PoR in the three-dimensional space (3D PoR)


Calibration process
from the user's side
When is it necessary to
perform this calibration?
Calibration from the user's side is a process necessary for creating a mapping for estimate the PoR (interpolation-based methods) or for estimate the visual axis (model-based methods)
Most eye tracking methods need to estimate a set of mathematical parameters through a calibration process from the user's side
These parameters can be calculated before each eye tracking session or just once for each user
The type of calibration process used by the eye tracker depends strongly on the eye tracking method used by the device
In general, interpolation-based eye tracking methods use a non-linear second order polynomial with 12 unknowns. The values of these unknowns can be calculated by Ordinary Least Squares (OLS) method
In general, model-based eye tracking methods use the calibration process from the user's side for correct measurement of the magnitude of the Kappa angle of each user

When is it necessary to perform this calibration?

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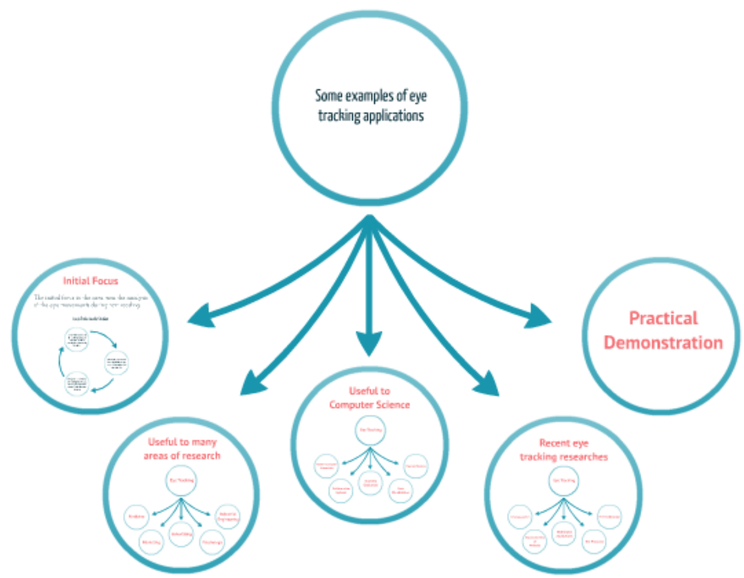
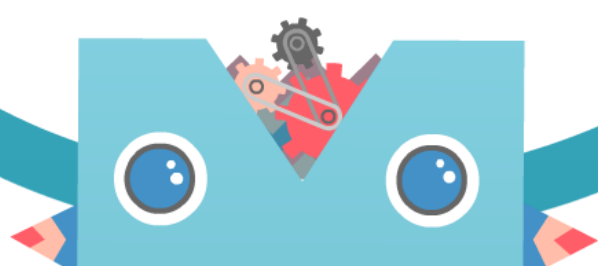
Eye Tracking Applications

Presentation of the development process of eye tracking systems



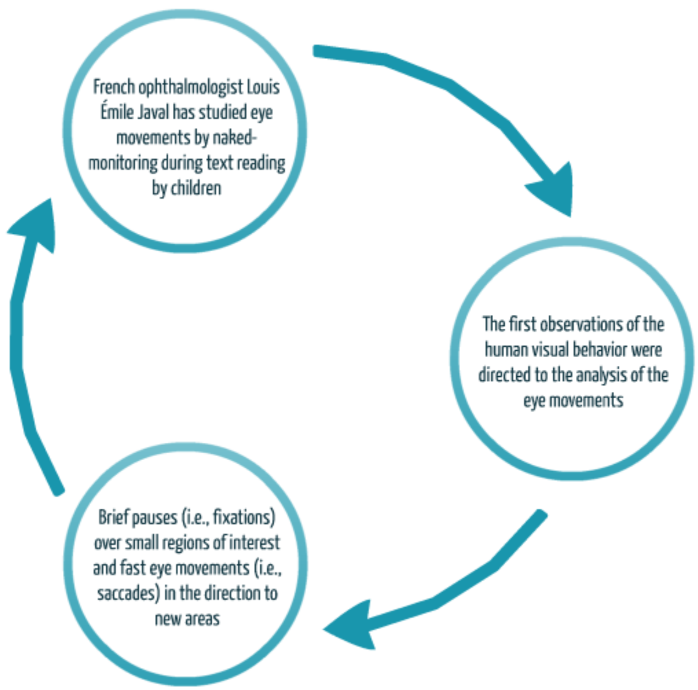


Some examples of eye tracking applications

Initial Focus

The initial focus in the area was the analysis of the eye movements during text reading

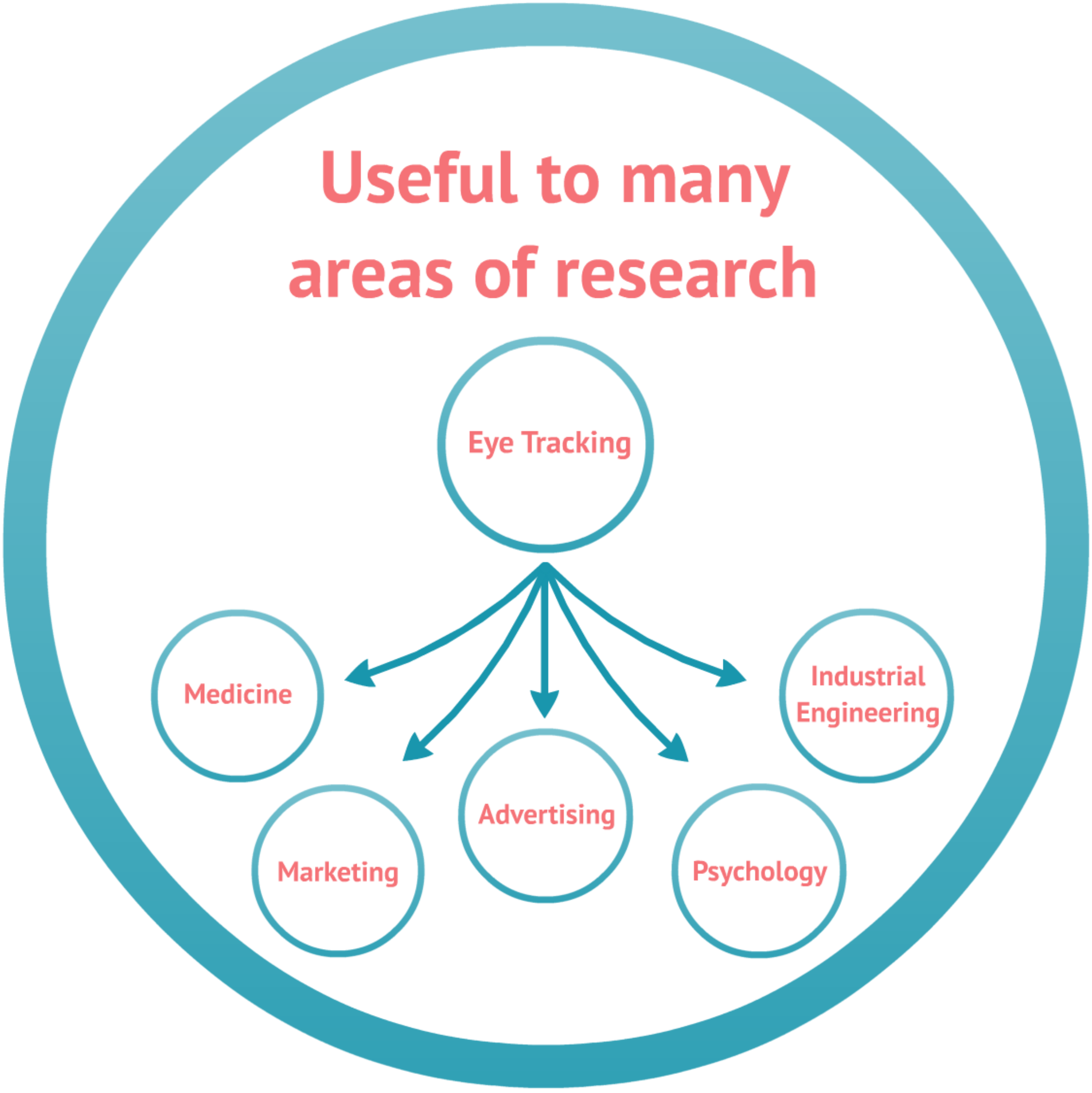
Louis Émile Javal's Studies

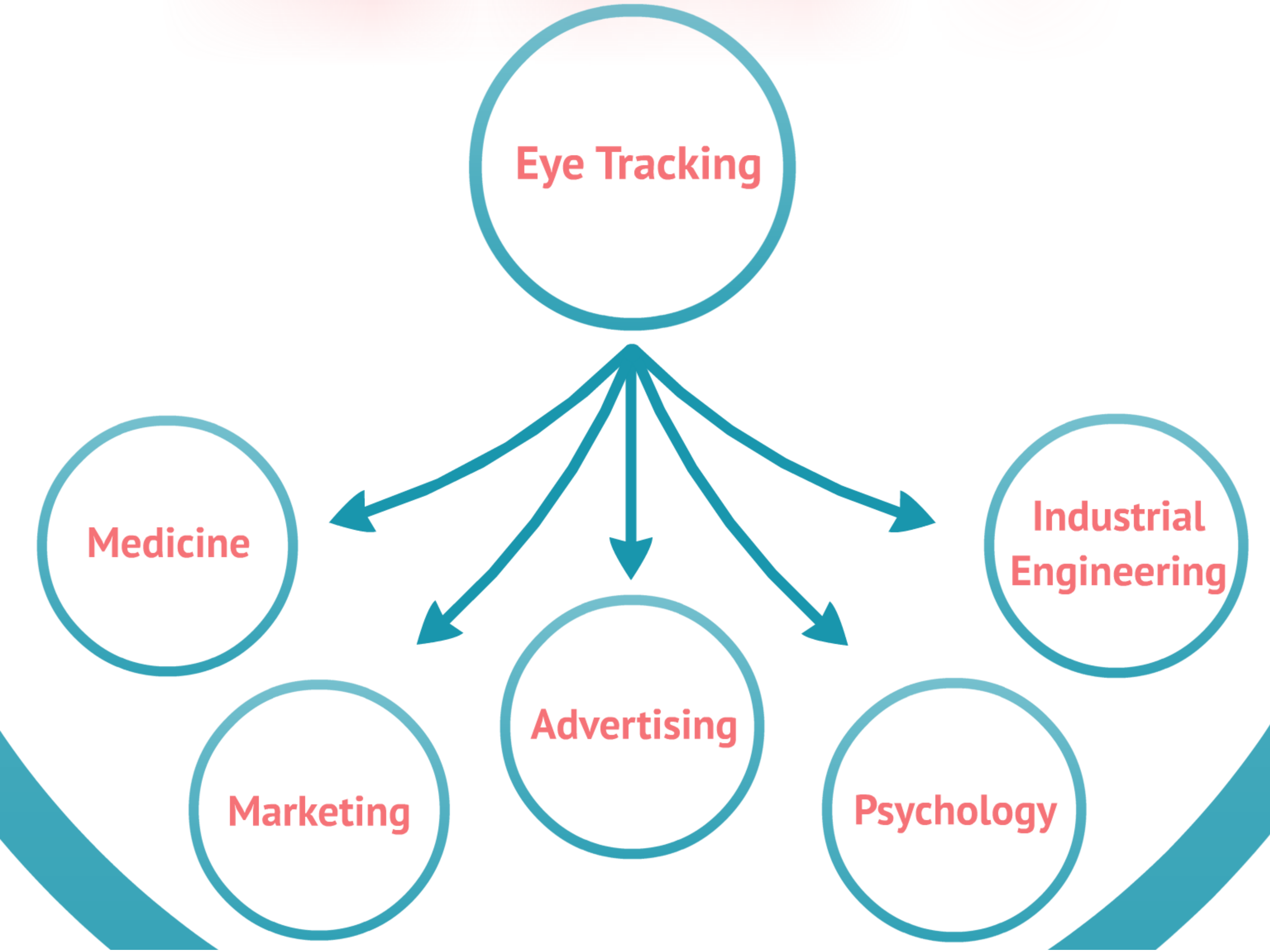


French ophthalmologist Louis Émile Javal has studied eye movements by naked-monitoring during text reading by children

The first observations of the human visual behavior were directed to the analysis of the eye movements

Brief pauses (i.e., fixations) over small regions of interest and fast eye movements (i.e., saccades) in the direction to new areas


Useful to many areas of research
Eye Tracking
Medicine
Industrial Engineering
Advertising
Marketing
Psychology


Eye Tracking
Medicine
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Marketing
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Medicine

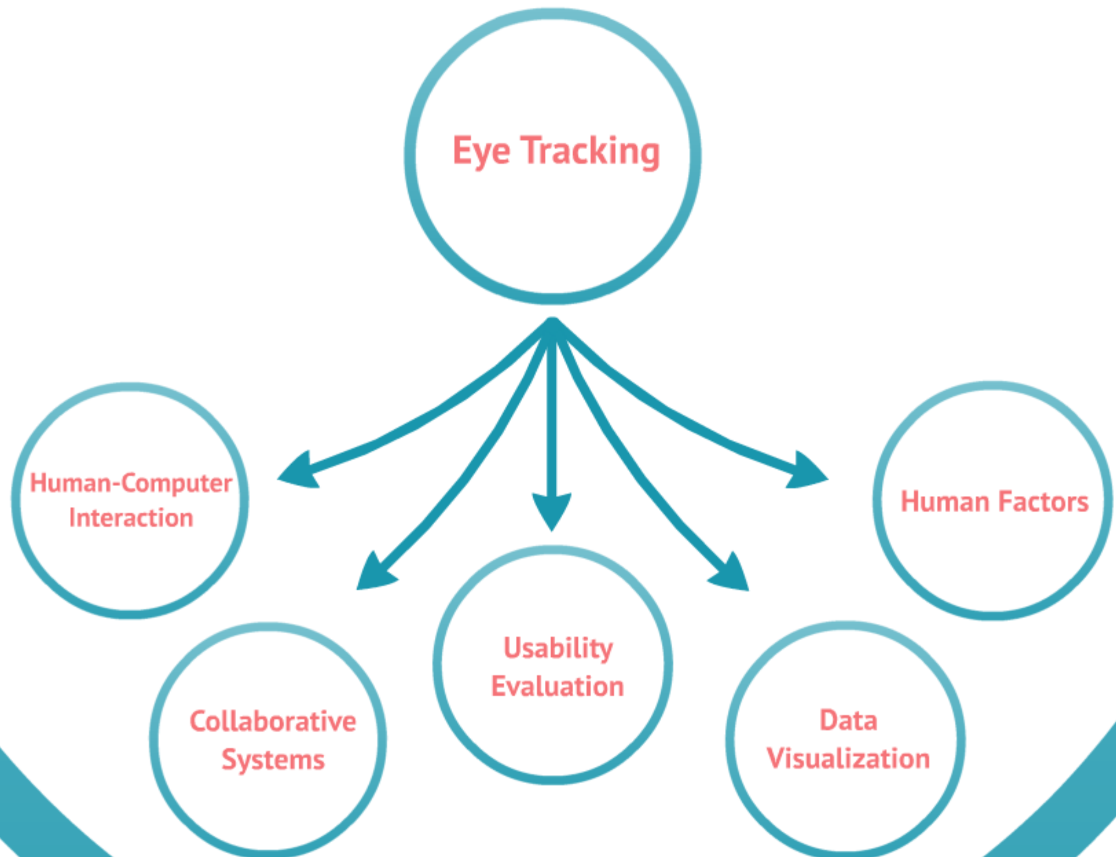
Marketing

Advertising

Psychology

Industrial Engineering

Useful to Computer Science



Human-Computer Interaction

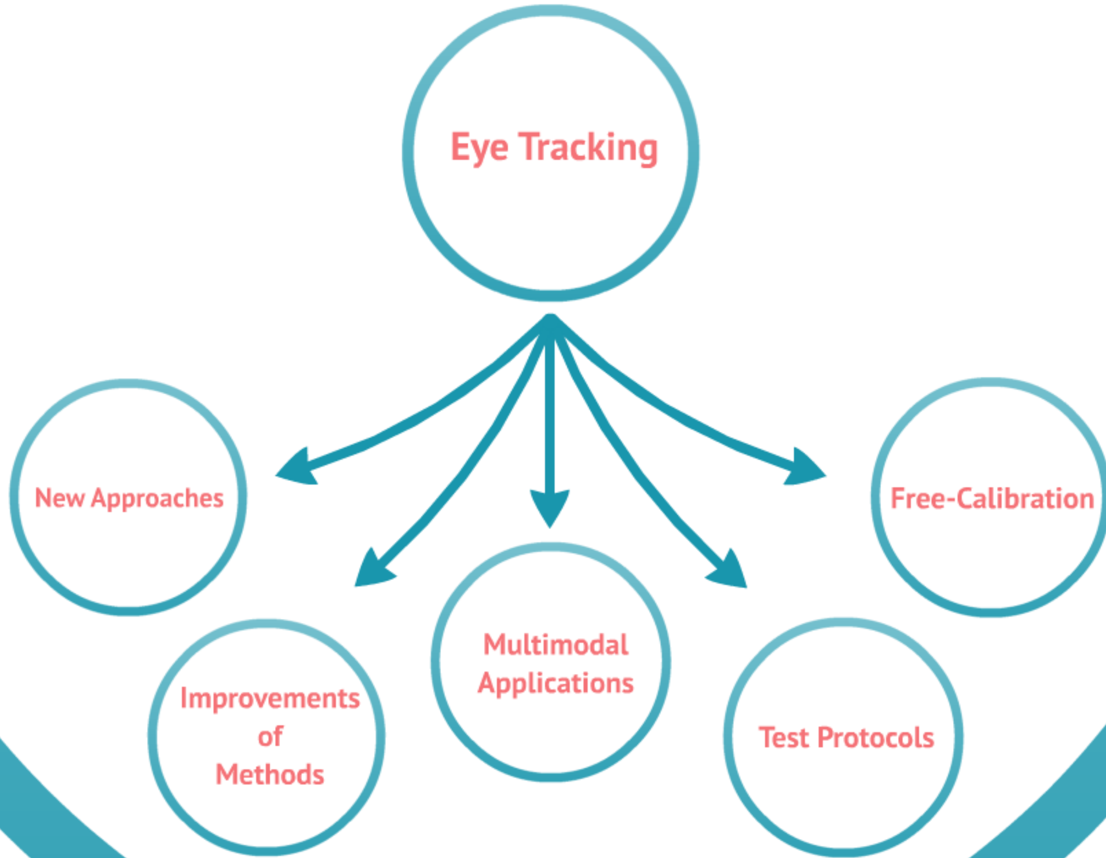
Collaborative Systems

Usability Evaluation

Data Visualization

Human Factors

Recent eye tracking researches



New Approaches

Improvements of Methods

Multimodal Applications

Test Protocols

Free-Calibration

Practical Demonstration

Final Considerations

Conclusions of the eye tracking concepts presented in the tutorial

General Considerations

Remote eye tracking systems share two common problems, namely:

- Complex settings of the eye tracking system may difficult the operation of the system by novice users
- The eye tracking system may fail to estimate the PoR, when the user's eyes fall out of the camera's visual field

Complex settings of the eye tracking system may difficult the operation of the system by novice users

The eye tracking system may fail to estimate the PoR, when the user's eyes fall out of the camera's visual field

Outstanding Research Problems

There are still some outstanding research problems in the field, such as:

- Free-calibrated in partially and non-calibrated setups
- Use of eye tracking in extreme or specific situations
- The presence of multiple uncalibrated cameras

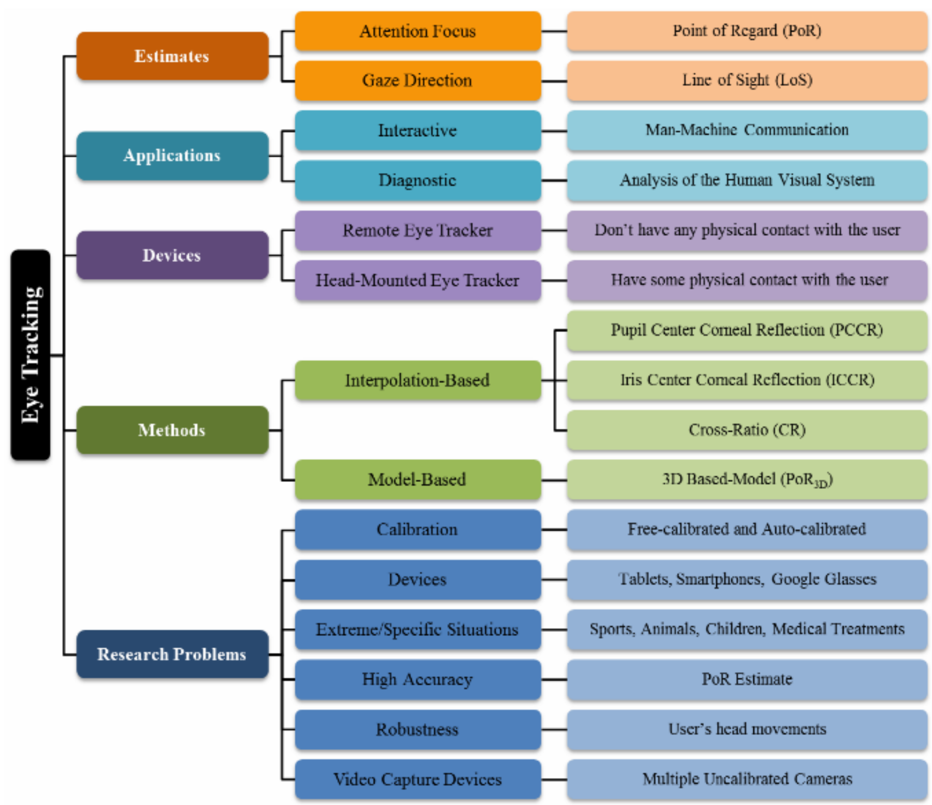
Free-calibrated in partially and non-calibrated setups

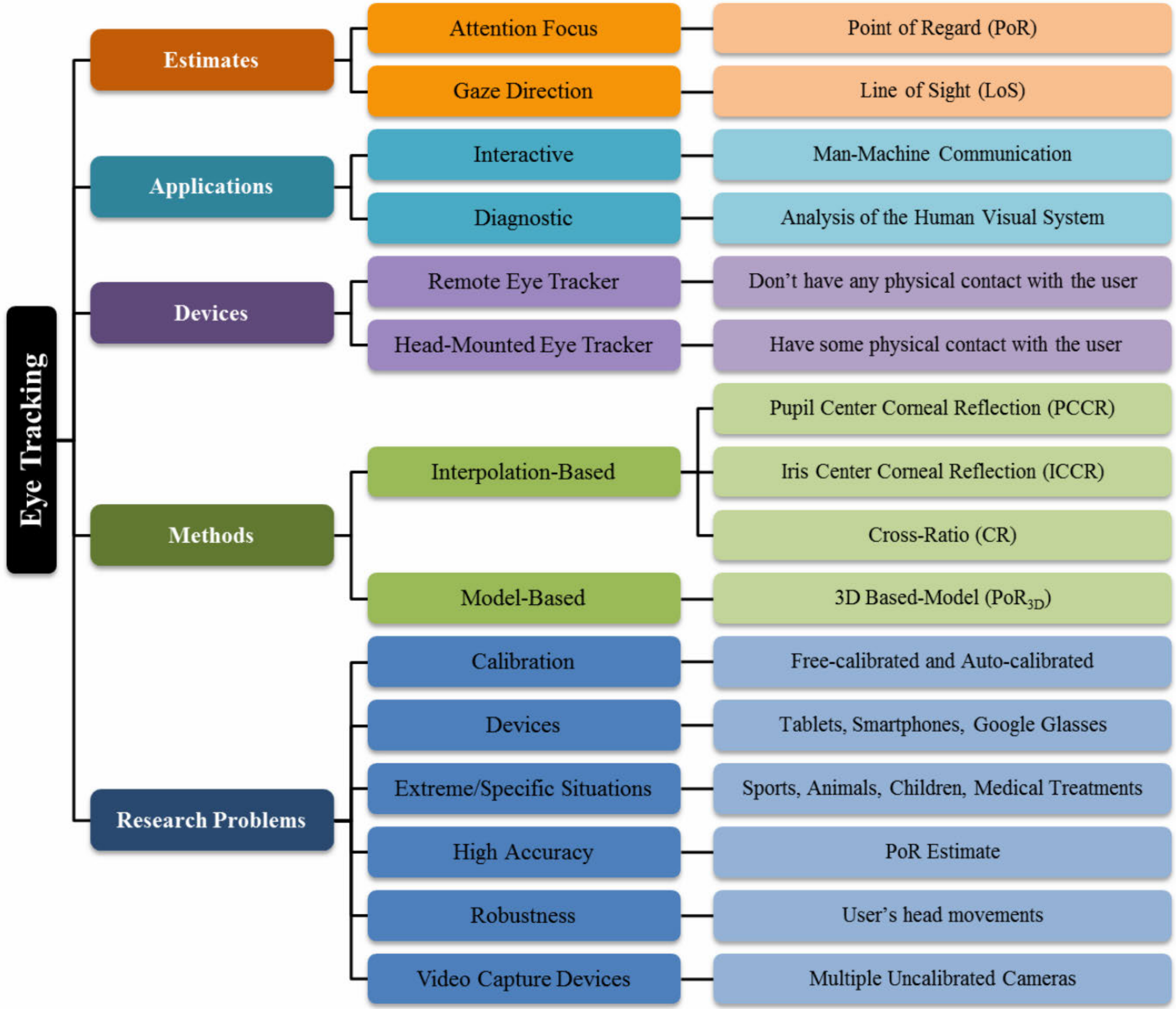
Use of eye tracking in extreme or specific situations

The presence of multiple uncalibrated cameras

Probably, the next generation of eye tracking systems will be directed to mobile devices (e.g., tablets, smartphones, PDA, GPS) and head-mounted devices (e.g., Google Glass, head-mounted displays)

Overview of our presentation




Eye Tracking
Estimates
Attention Focus
Point of Regard (PoR)
Gaze Direction
Line of Sight (LoS)
Applications
Interactive
Man-Machine Communication
Diagnostic
Analysis of the Human Visual System
Devices
Remote Eye Tracker
Don't have any physical contact with the user
Head-Mounted Eye Tracker
Have some physical contact with the user
Methods
Interpolation-Based
Pupil Center Corneal Reflection (PCCR)
Iris Center Corneal Reflection (ICCR)
Cross-Ratio (CR)
Model-Based
3D Based-Model (PoR$_{3D}$)
Research Problems
Calibration
Free-calibrated and Auto-calibrated
Devices
Tablets, Smartphones, Google Glasses
Extreme/Specific Situations
Sports, Animals, Children, Medical Treatments
High Accuracy
PoR Estimate
Robustness
User's head movements
Video Capture Devices
Multiple Uncalibrated Cameras

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Thank you!!!